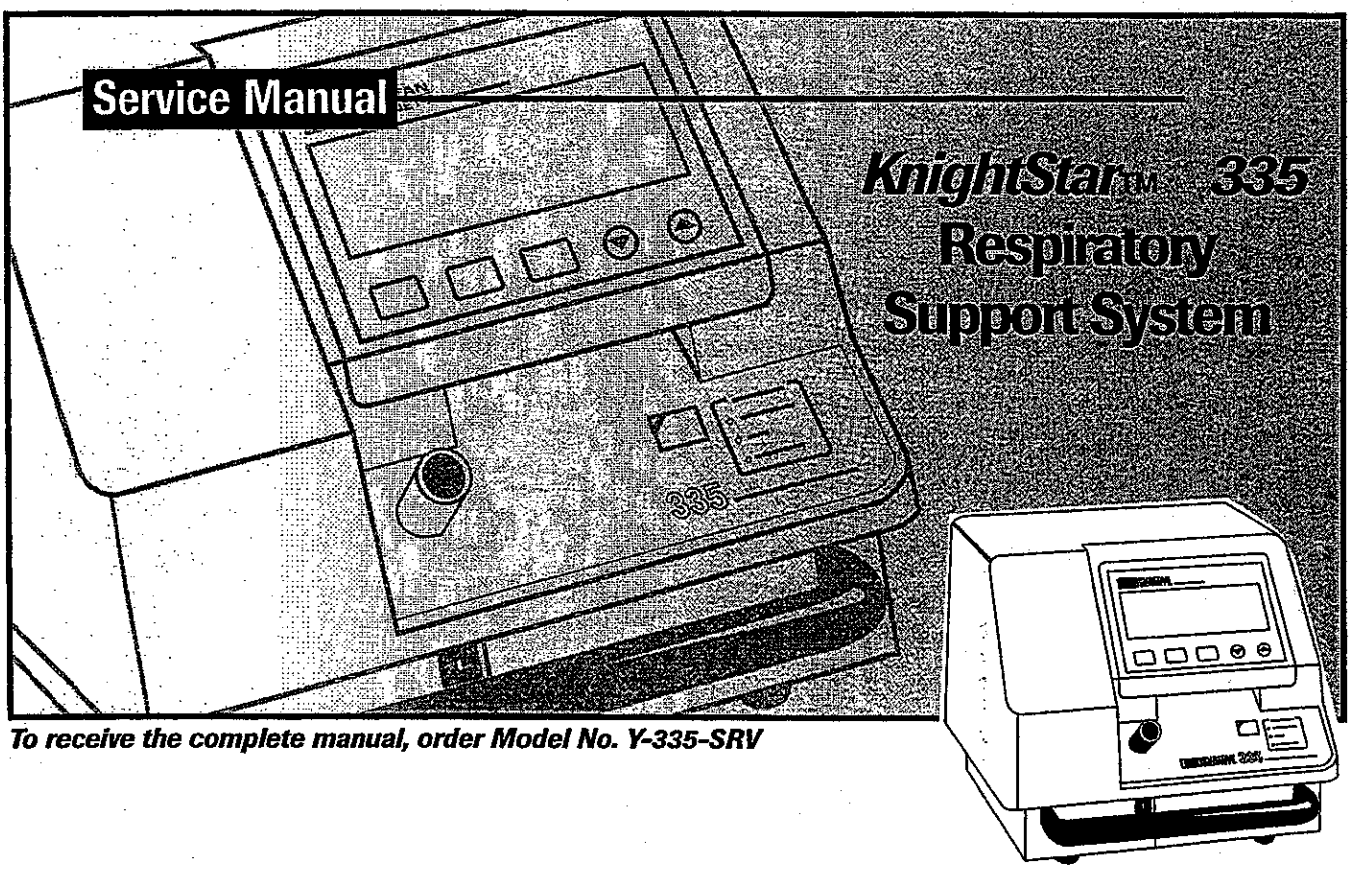
Service Manual

KnightStar™ 335 Respiratory Support System



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Part No. Y-780551-00A Rev. B

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Preface

This manual provides information needed to service the *KnightStar 335*® Respiratory Support System. This information is intended for use by technicians or personnel qualified to repair and service medical equipment. The information is not all-inclusive and may not be applicable to future models.

Questions regarding service of the *KnightStar 335* respiratory support system should be directed to the Technical Support Department. Telephone number (800) 497-3787.

Information contained in this document, including performance specifications, are subject to change without notice.

Nellcor Puritan Bennett makes no warranty of any kind with regard to the material in this manual, including but not limited to the implied warranties of merchantabilities and fitness for a particular purpose.

Nellcor Puritan Bennett shall not be liable for errors contained herein or for incidental or consequential damages in connection with either providing this manual or the use of material in this manual.

Definition of Statements

Statements in this manual preceded by the following words are of special significance.

WARNING: Means there is a possibility of injury or death to yourself or others.

CAUTION: Means there is the possibility of damage to the unit or other property.

NOTE: Indicates points of particular interest for more efficient and convenient operation.

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Section 1. General Information

The *Patient Guide* is intended for use by the patient at home. It includes information for set-up, operation and routine maintenance of the *KnightStar™ 355* respiratory support system. Refer to the "Table of Contents" of the *Patient Guide* for information contained within.

The *Clinical Guide* is intended for use in sleep disorder labs. It contains information for set-up, operation and routine maintenance of the *KnightStar 355* respiratory support system and associated modules. Refer to the "Table of Contents" of the *Clinical Guide* for information contained within.

For further information, contact the following:

Manufactured by:
Nellcor Puritan Bennett
a subsidiary of Mallinckrodt Inc.
2800 Northwest Blvd.
Minneapolis, MN 55441-2625 U.S.A.
Phone 612.694.3500
Fax 612.694.3600

Corporate Headquarters:
Mallinckrodt Inc.
675 McDonnell Boulevard
P.O. Box 5840
St. Louis, Missouri 63134 USA
Phone: 314.654.2000

European Office:
Mallinckrodt Europe BV
Hambakenwetering I
5231 DD 's-Hertogenbosch
The Netherlands
Phone: +31.73.6485200
Fax: +31.73.6410915

Table 1-1 Performance Specifications

Physical Characteristics

Parameter	*Measurement*
Base Unit Dimensions with Control Module:	
Height	10.25"
Width	12"
Depth	15.25"
Weight	19 lbs (8.6 kg)
Shipping Dimensions:	
Height	17.5"
Width	22"
Depth	15"
Shipping Weight	26.5 lbs (11.9 kg)

Electrical Requirements

Parameter	*Measurement*
AC Power	Accepts 100 to 240 VAC 50 or 60 Hz
Current Leakage	Less than 100 microamps
Power consumption:	
Unit turned on	350 VA max
Power Cord	Three-wire grounded type
Analog Output Connections (Control Module Type 1)	Mini Phone Jack (3.5mm)
Base Unit to Module Connection	25 pin D-Subminiature
AC Fuses	100 VAC operation, 3.15A 120 VAC operation, 3.15A 220/240 VAC operation, 2.0 A
Remote Control	9 VDC Battery

Environmental Requirements

Parameter	*Specification*
Storage Temperature	-40 to 158° F (-40 to 70° C)
Operating Temperature	35 to 110° F (2 to 43.3° C)

Operational Characteristics

Parameter	*Measurement*
Pressure Range	
CPAP Mode	+3 to +20 cmH_2O in 1 cmH_2O increments
I/E PAP Mode	
Inspiratory	+3 to +35 cmH_2O in 1 cmH_2O increments
Expiratory	+3 to +20 cmH_2O in 1 cmH_2O increments
A/C (Assist/Control) Mode	
Inspiratory	+3 to +35 cmH_2O in 1 cmH_2O increments
Expiratory	+3 to +20 cmH_2O in 1 cmH_2O increments
A/C (Assist/Control) Mode Only	
Back Up Rate	3 to 30 bpm in 1 bpm increments
I:E (Inhale to Exhale) Ratio	1:1.0 to 1:4.0 in 0.5 increments
Sensitivity	
(I/E PAP and A/C Modes only)	Scale of 1 to 5 with 1 being most sensitive
Delay	0 to 30 minutes in 5 minute increments
Ramp	1 to 3 cmH_2O per minute in 1 cmH_2O increments
Audible Alarm	Scale of 0 to 3 with 0 being alarm silenced. Alarm volume is set to full during inoperative or power failure alarms.

Section 2. Theory of Operation

This section describes the operational theory of the *KnightStar 335* respiratory support system and includes simplified pneumatic and electronic/electrical block diagrams. More detailed information for actual component identification or mounting location may be obtained by referring to the appropriate exploded view illustration located in Section 4 of this manual.

Table 2-1 Acronyms and Abbreviations

AC	Alternating Current
A/C	Assist Control
CPU	Central Processing Unit
cmH_2O	Centimeters of Water
CPAP	Continuous Positive Airway Pressure
dBA	Decibels
DC	Direct Current
EMI	Electromagnetic Interference
EPAP	Expiratory Positive Airway Pressure
ESD	Electro Static Discharge
Hz	Hertz
I/E PAP	Inspiratory/Expiratory Positive Airway Pressure
I/E Ratio	Inspiratory/Expiratory Ratio
IPAP	Inspiratory Positive Airway Pressure
IR	Infrared
LCD	Liquid Crystal Display
lpm	Liters per Minute
PCB	Printed Circuit Board
PFI	Power Failing Indicator
VAC	Voltage Alternating Current
VDC	Voltage Direct Current

2.1 Base Unit System Overview

The *KnightStar 335* respiratory support system (Figures 2-1 and 2-2) is a portable flow generator, electrically powered and electronically controlled. The *KnightStar 335* consists primarily of a motor/blower assembly (capable of providing a large flow of filtered air at low levels of airway pressure), a rotary actuator and three electronic printed circuit board (PCB) assemblies: Central Processing Unit PCB, Power Controller PCB and Power Supply PCB (Figure 2-3).

Two transducers (Figure 2-3) and a rotary actuator (Figure 2-3) are used to control the delivery of a breath to the patient. A flow transducer is used to detect the patient's inspiratory and expiratory efforts. When

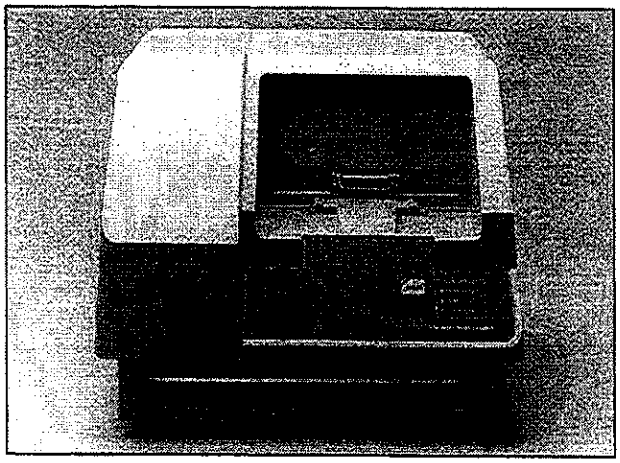

Figure 2-1: KnightStar 335 Base Unit (front view)

there is a sufficient change in flow, the machine will change from exhalation to inspiration or vice versa. A pressure transducer is used to monitor the pressure in the patient circuit. Information from the pressure transducer is used to adjust the rotary actuator to maintain the operator selected pressures.

Several modes of operation are available: CPAP, I/E PAP, and A/C (Assist Control). The CPAP (Continuous Positive Airway Pressure) mode provides the same positive pressure for both inspiration and exhalation. When the I/E PAP (Inspiratory/Expiratory Positive Airway Pressure) mode is used, different pressures can be applied to inspiration and exhalation. In the A/C (Assist Control) mode the operator selects a backup respiratory rate and an I:E (Inspiratory to Expiratory) ratio. As long as the patient is breathing, the machine is in the "Assist" mode delivering the I/E PAP pressures. If the *KnightStar 335* does not sense patient breathing

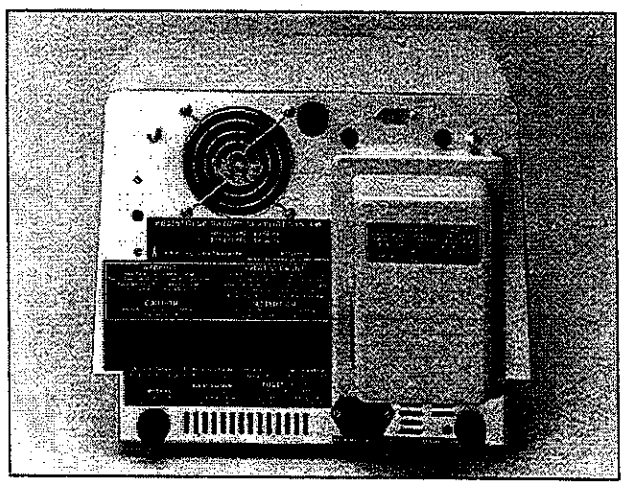

Figure 2-2: KnightStar 335 Base Unit (back view)

efforts for a period of time equal to the patient's average respiratory rate plus five seconds it will switch to the "Control" mode. The *KnightStar 335* uses the I/E PAP pressures at the selected respiratory rate and I:E ratio. It will stay in the "Control" mode until the patient resumes breathing and will then switch back to the "Assist" mode.

Both the inhale and exhale pressure ranges can be adjusted independently. Inhalation pressure is adjustable from +3 to +35 cmH_2O and exhalation pressure can be adjusted from +3 to +20 cmH_2O. Modes and breath parameters are accessed through the Control Module Type 1 discussed in the next section.

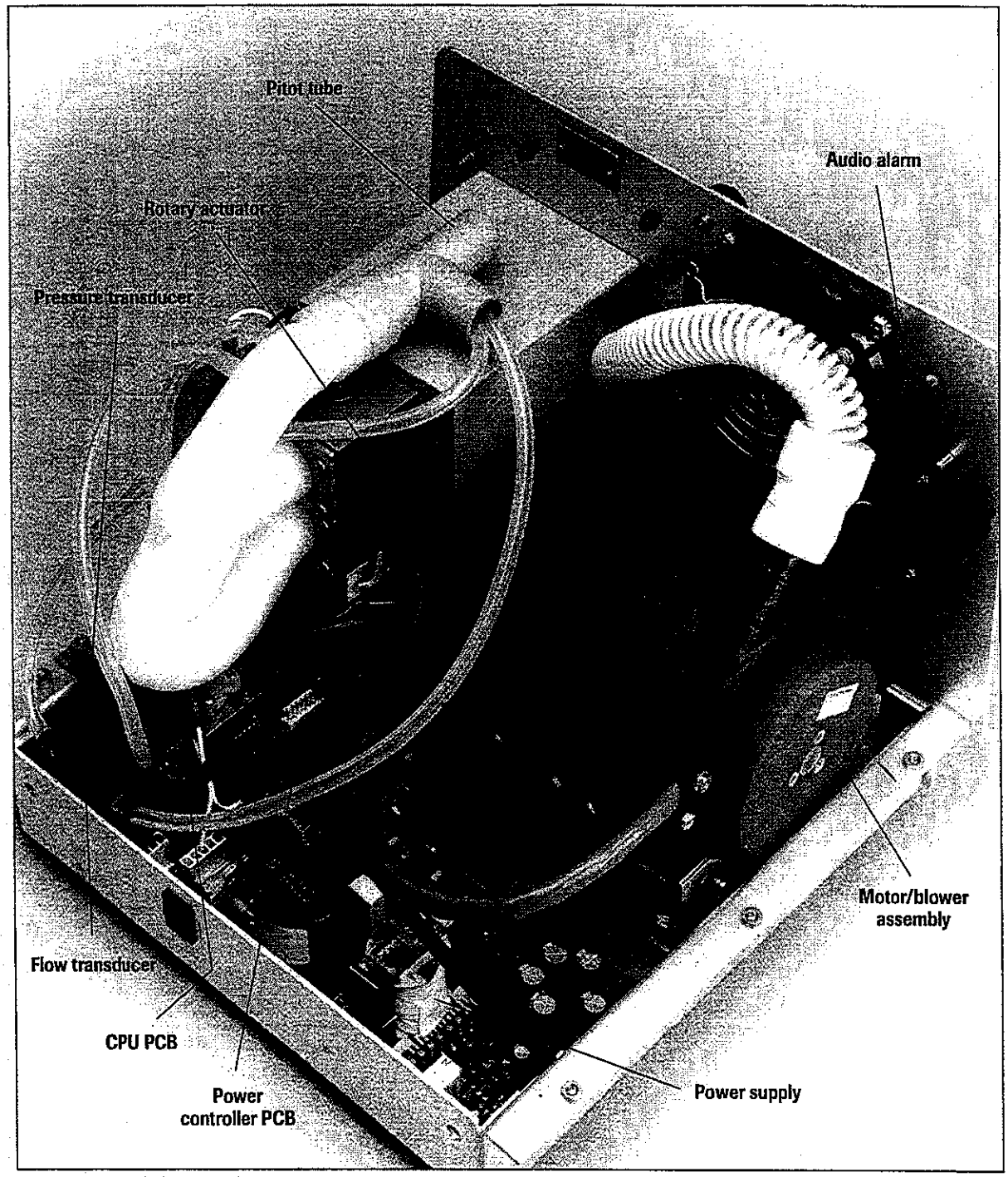

Figure 2-3: *KnightStar 335* Internal Components

2.2 *KnightStar 335* Module Overview

Located on the front of the *KnightStar 335* base unit is a docking station where one of three modules can be connected. The Control Module Type 1 (Figure 2-4) is intended for use by hospital sleep labs and home care providers and is used to set patient parameters.

A cable up to 100 feet long can be connected to the

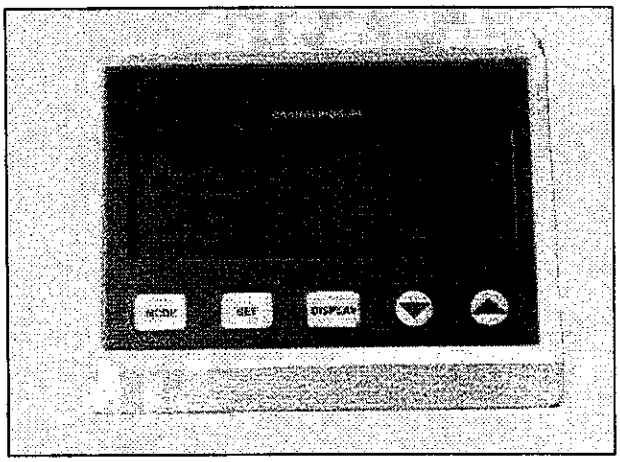

Figure 2-4: Control Module Type 1

Base Unit and the Control Module Type 1. This allows the user to make adjustments to the *KnightStar 335* base unit and take measurements without disturbing the patient. The Control Module Type 1 also provides

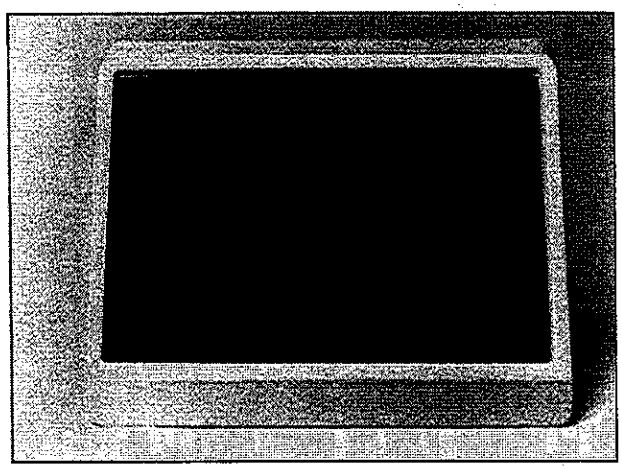

Figure 2-5: Infrared Module

analog outputs that can be used with a polysomnograph machine. An Infrared Module (Figure 2-5) can be used in conjunction with the hand held IR Remote Control (Figure 2-6) by the patient to turn the unit on and off and to select the delay function. A Blank

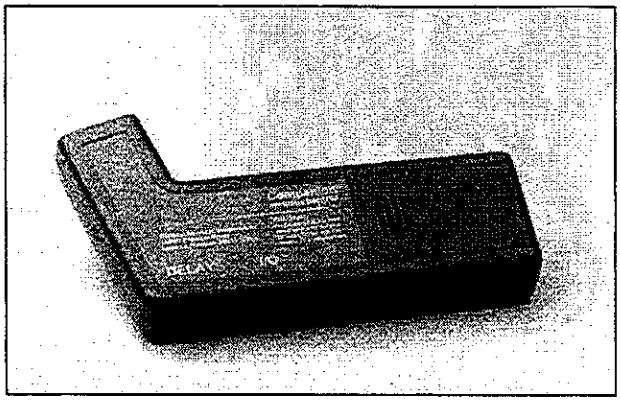

Figure 2-6: IR Remote Control

Module (Figure 2-7) is provided for cosmetic reasons when no other module is in use. The *KnightStar 335* respiratory support system can also be used with no modules connected.

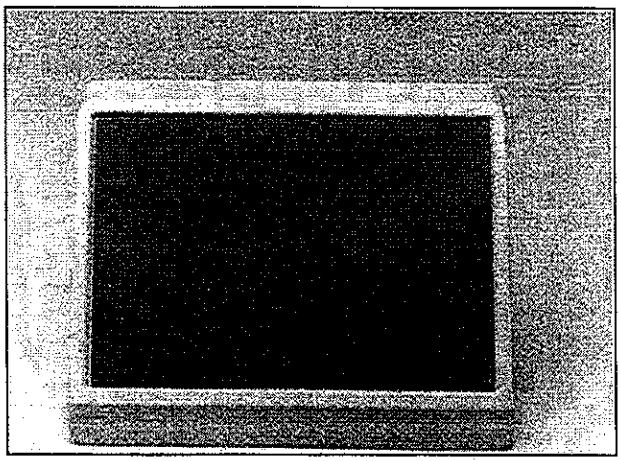

Figure 2-7: Blank Module

2.3 Pneumatic System

Refer to Figure 2-8 for a simplified diagram of the *KnightStar 335* pneumatic system. It is intended for the diagram to be fully opened while reading this text. Key components of the pneumatic system are shown in their correct location pneumatically in Figure 2-8. Photos of the components are included with the appropriate text in the following section. The pneumatic system consists of the following key components:

- Baffle
- Inlet Filter
- Baffle Plate
- Baffle Housing
- Motor/Blower Assembly
- Rotary Actuator Assembly
- Pressure Transducer
- Pressure Switch
- Pitot Tube
- Flow Transducer
- Outlet Connector

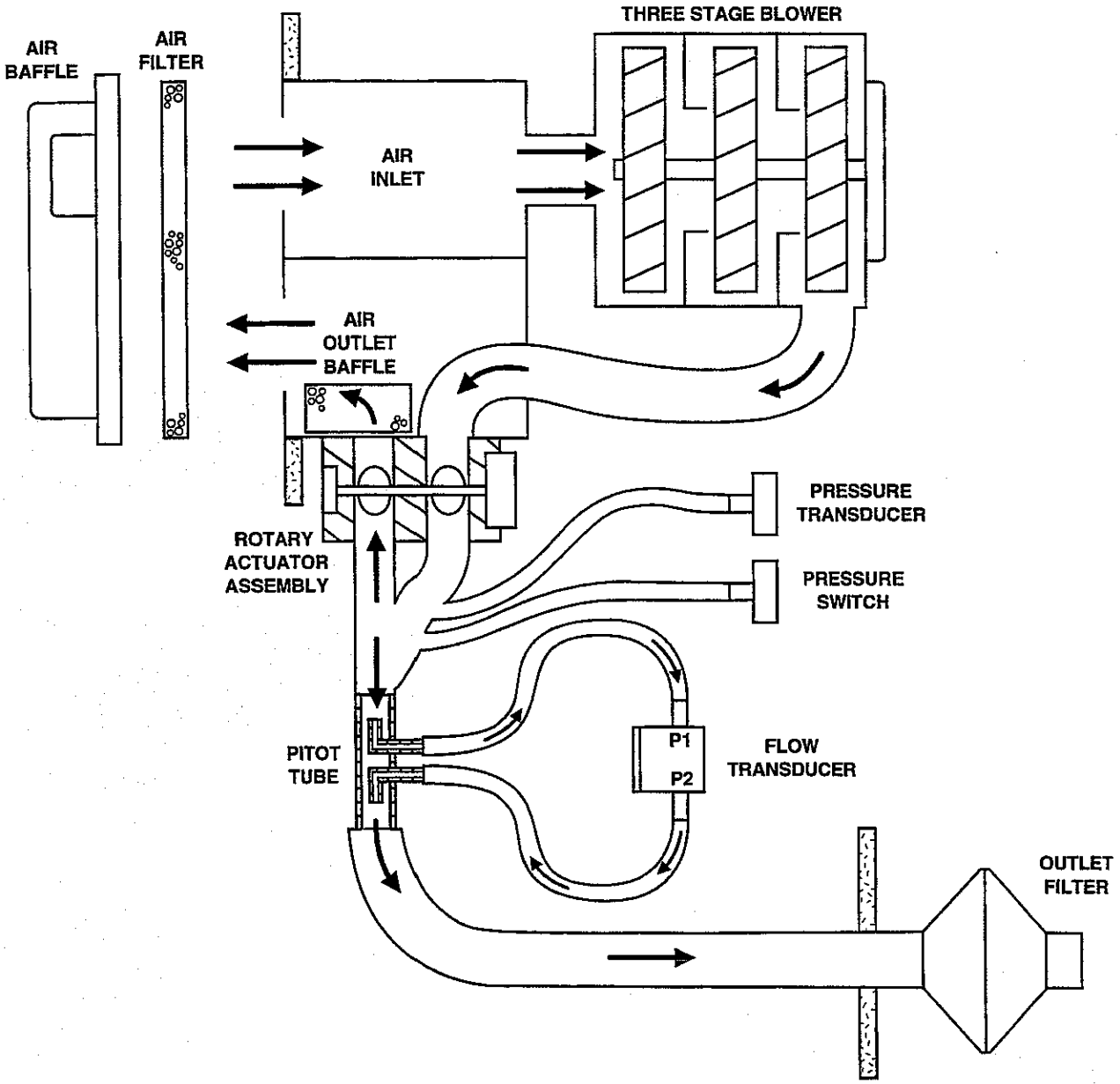

Figure 2-8: Pneumatic Diagram

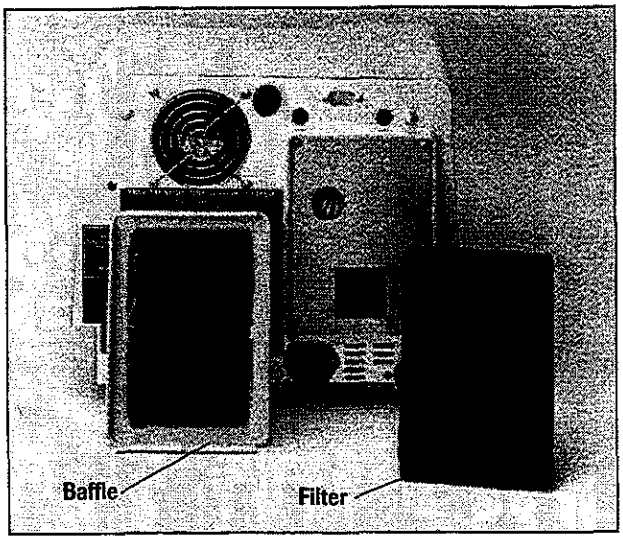

Figure 2-9: Inlet Filter and Baffle

Inlet Filter and Baffle

Room air is drawn into the *KnightStar 335* unit through the Baffle and Inlet Filter (Figure 2-9). Approximately 95% of the particles between 1 and 40 microns are trapped by the inlet filter. The baffle is foam lined and has two chambers used to reduce the amount of noise generated by air flow through the *KnightStar 335*. The Baffle Housing (Figure 2-10) contains two chambers: the lower chamber is for air inlet, the upper chamber is used to expel excess flow from the motor/blower assembly. To further muffle sound caused by air flow, the housing is lined with foam and is covered with a foam lined baffle plate.

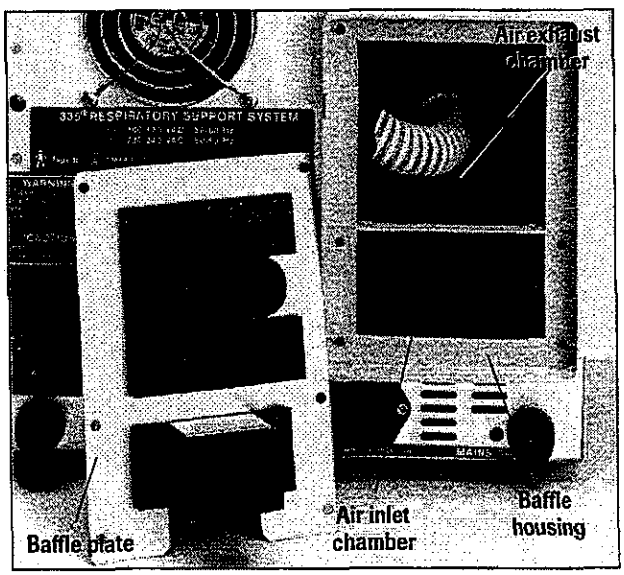

Figure 2-10: Baffle Plate and Housing

Motor/Blower Assembly

The Motor/Blower Assembly (Figure 2-11) provides the pressure and flow used to drive the *KnightStar 335* respiratory support system. Filtered air is pulled into the motor/blower inlet port. The motor/blower assembly consists of a 24V brushless DC motor and a three-stage flow generator. The motor is capable of producing a minimum of 255 lpm at 45 cmH_2O. Blower speed is based on the IPAP pressure selected by the operator.

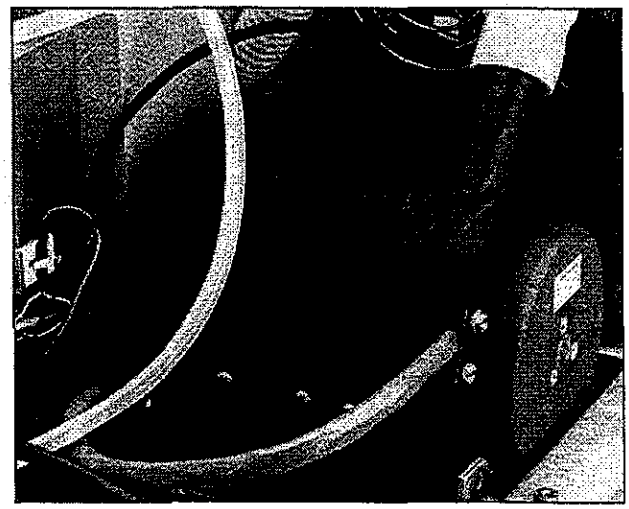

Figure 2-11: Motor/Blower Assembly

Rotary Actuator Assembly

Flow from the motor/blower assembly is controlled by the Rotary Actuator Assembly (Figure 2-12). This assembly is divided into an upper and lower chamber

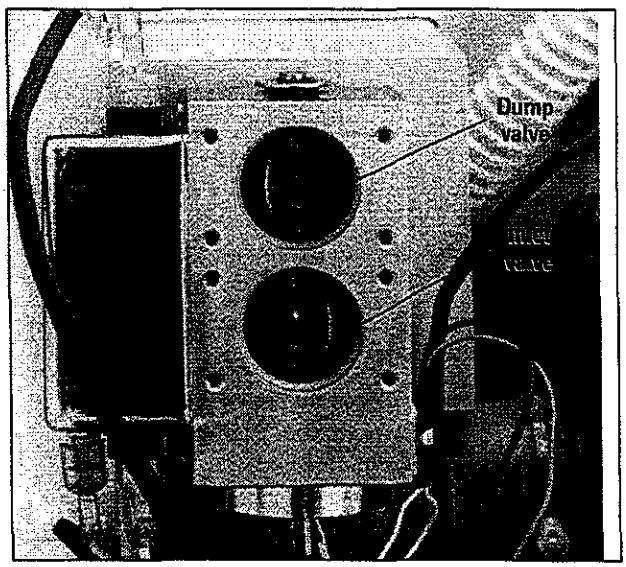

Figure 2-12: Rotary Actuator Assembly

each containing a butterfly valve. The lower butterfly valve is called the inlet valve. It directs flow to the patient. The upper butterfly valve is called the dump valve. Excess flow is diverted to the upper chamber of the housing by the dump valve. Both of the butterfly valves are mounted on a common shaft which passes through each chamber in the rotary actuator assembly and can rotate up to 50 degrees. A torque actuator located on the bottom of the rotary actuator assembly moves the butterfly valves. As one valve opens the other closes.

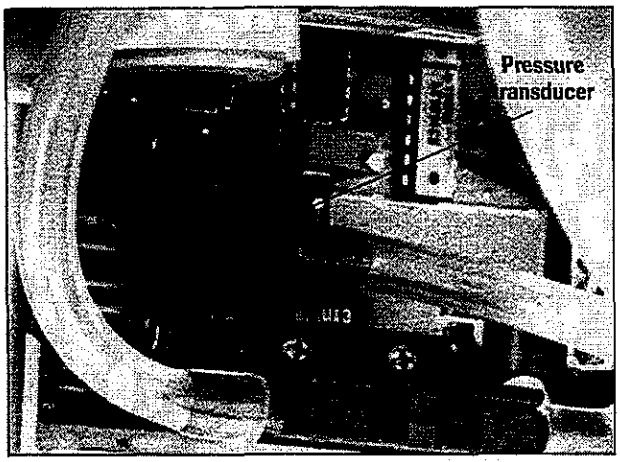

Figure 2-13: Pressure Transducer

Pressure Transducer

Movement of the butterfly valves is determined by the difference between the pressure set point and the actual pressure measured by the Pressure Transducer (Figure 2-13). A pressure signal is sent to the Central Processing Unit, Printed Circuit Board (CPU PCB) which in turn determines where to position the butterfly valves. By adjusting the position of the butterfly valves in the rotary actuator assembly, prescription pressures can be accurately maintained. The pressure transducer will also produce pressure data which can be accessed by the Control Module Type 1 and sent to a polysomnograph to be recorded.

Pressure Switch

The Pressure Switch (Figure 2-14) is normally closed and is preset to 50 cmH_2O. Pressure greater than the set point will cause the switch to open. When the switch opens the motor/blower assembly will be turned off and an "Inoperative" indicator will be illuminated.

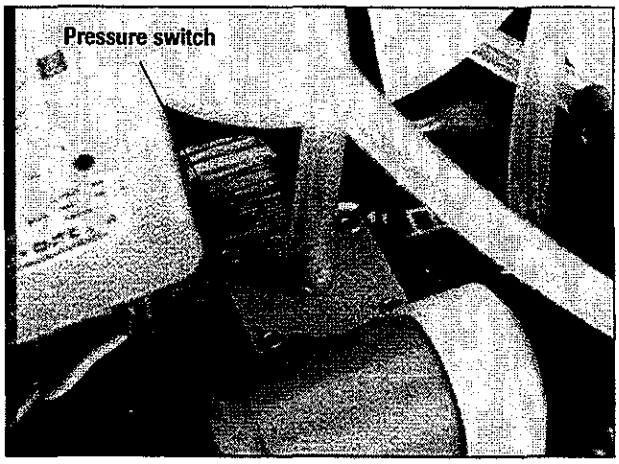

Figure 2-14: Pressure Switch

Pitot Tube

The Pitot Tube (Figure 2-15) is placed in the main flow of air to the patient. One leg of the pitot tube will divert a small fraction of the patient flow to the flow transducer. Diverted flow is proportional to the total flow being carried in the circuit. Diverted air passes through the flow transducer and back into the main flow via the second leg of the pitot tube (Figure 2-16).

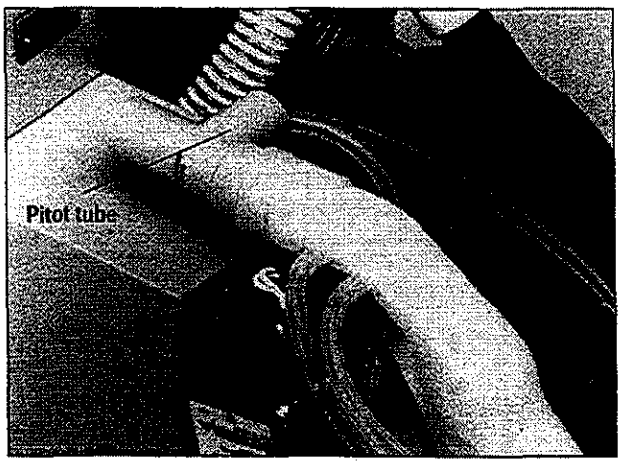

Figure 2-15: Pitot Tube

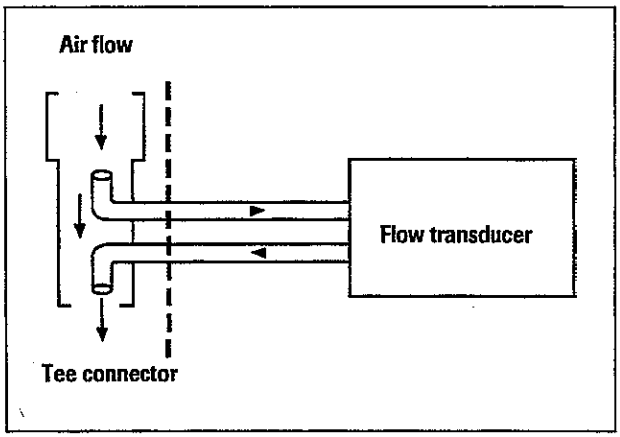

Figure 2-16: Pitot Tube Diagram

Flow Transducer

A Flow Transducer (Figure 2-17) is used to determine patient breathing efforts. Information from the flow transducer determines when the *KnightStar 335* switches to either the inspiratory or expiratory pressure. Tidal volume and flow rates can also be determined by information gathered from the flow transducer. This information is valuable for sleep studies.

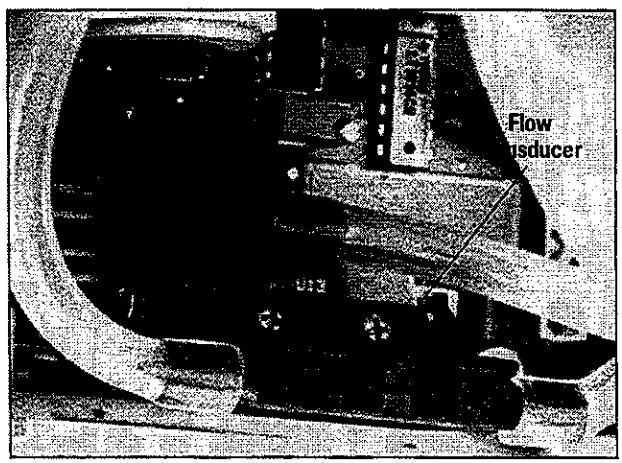

Figure 2-17: Flow Transducer

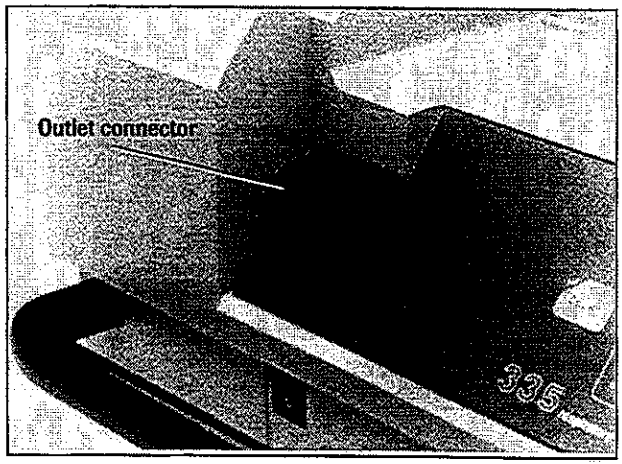

Figure 2-18: Outlet Connector

Outlet Connector

The Outlet Connector (Figure 2-18) is the interface between the patient and the machine. Internal flow of the *KnightStar 335* is connected to the outlet connector. The patient connects their circuit at this point.

2.4 Electrical/Electronic Operation

Refer to Figure 2-19 for a simplified electrical/electronic system block diagram of the Base Unit (Figure 2-1). The electrical/electronic system consists of the following components/system blocks:

KnightStar 335 Base Unit

- AC Power Receptacle
- EMI Filter
- Power Switch
- Power Supply
- Keypad
- Central Processing Unit PCB
  - Microprocessor
  - Memory
  - 10 VDC Module
  - Flow Transducer
  - Pressure Transducer
  - Breath Triggering Interface
  - Pulse Width Modulator
  - Keypad Interface
  - Control Module Interface
  - Memory
  - Battery
  - Amplifier
  - Flow Signal Conditioner
  - Tidal Volume Interface
  - Analog Signal Control
  - Calibration Signal Generator
- Power Controller PCB
  - AC Sense
  - Pilot Lamp
  - Power Failing Indicator
  - Voltage Regulators
  - Motor Controller
  - Pressure Controller
  - Audio Alarm Volume Control
  - Fan Controller

Control Module Type I

- Connector PCB
  - Analog Outputs
  - Voltage Regulator
- Master PCB
  - Signal Conditioner
  - Backlight Drive
  - Attenuator
  - Switch Decode
- Switch Pad
  - LCD PCB
  - LCD Drive
  - LCD Backlight

Infrared Module

- IR Control Module PCB
  - Voltage Regulator
- Receiver PCB
  - Rate Switch
  - IR Detector
  - Signal Convertor

Infrared Remote Control

- Rate Switch

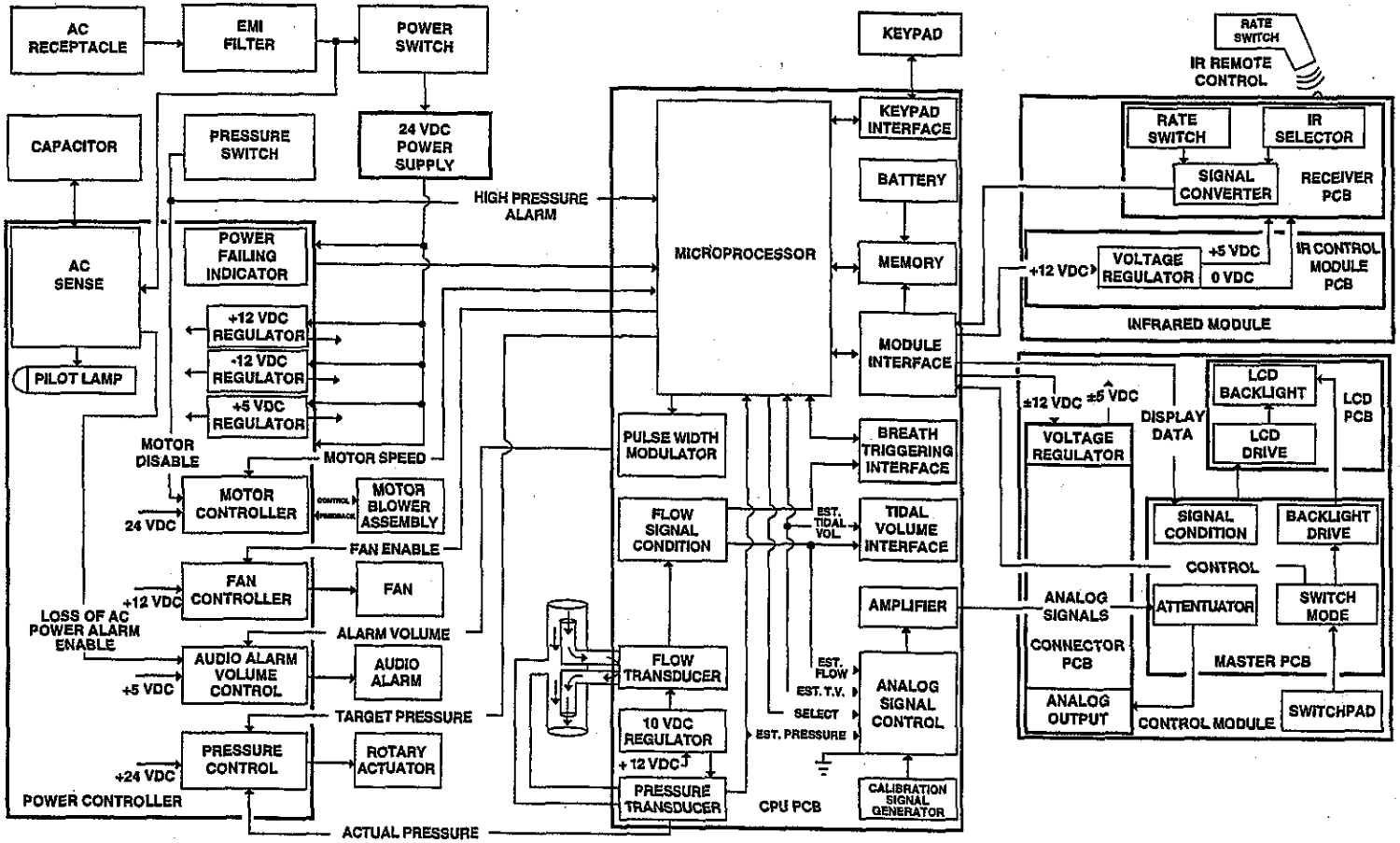

Figure 2-19: Simplified Electrical/Electronic Block Diagram

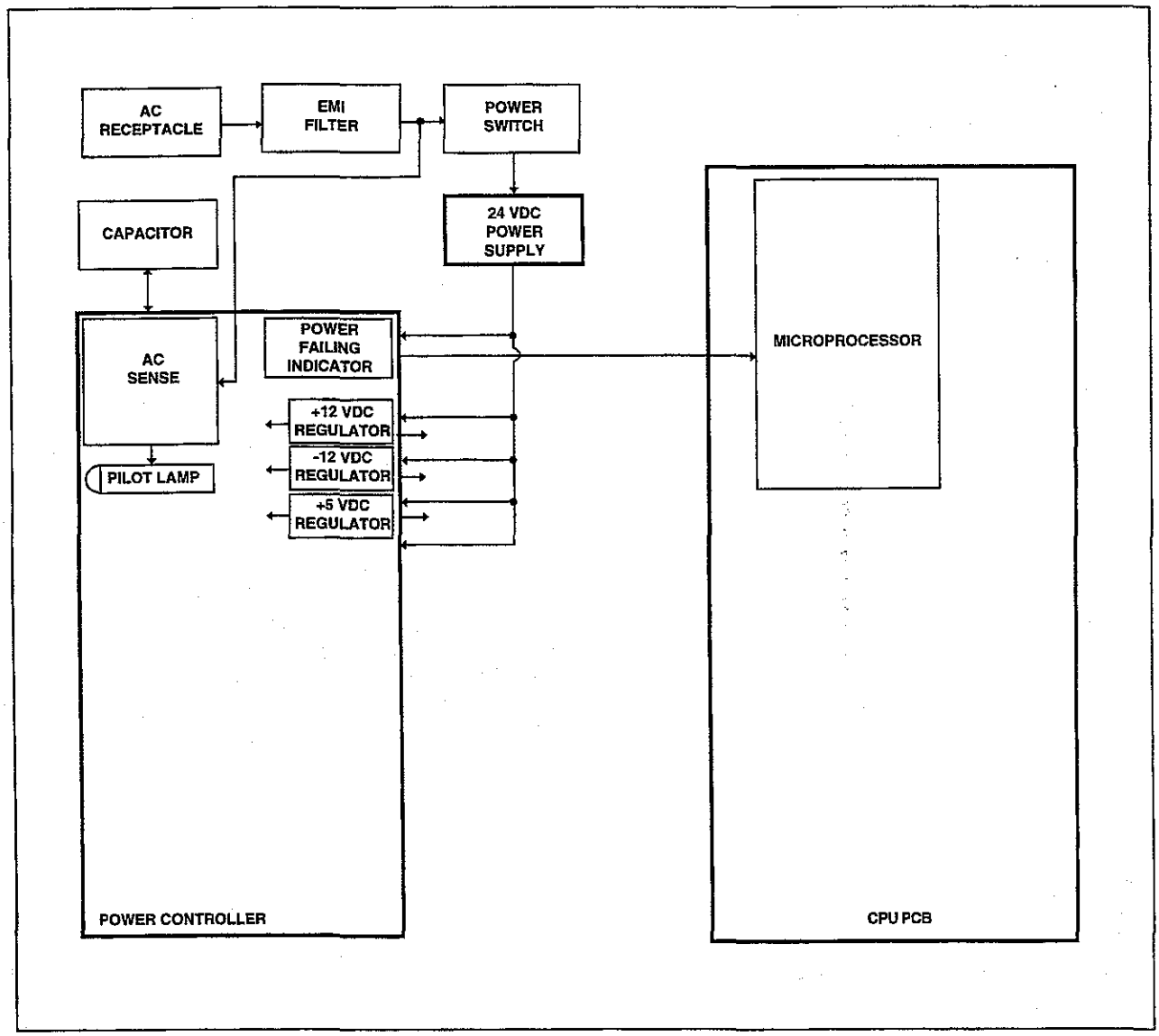

Figure 2-20: Power Distribution

2.4.1 *KnightStar 335* Base Unit Power Distribution

AC power is routed to the *KnightStar 335* via an AC power cord. The AC power cord may be detached from the AC power receptacle mounted on the rear panel of the *KnightStar 335*. The AC power receptacle contains two separate fuses: one for the "Hot" and one for the "Neutral" AC power lines. Replacement of the fuses requires removal of the integral fuse drawer located on the power receptacle just below the AC power cord connection.

After passing through the AC power receptacle, power is routed to an EMI Filter (Figure 2-21). This filter is used to protect the *KnightStar 335* from noise and power spikes which may have entered the unit through the power cord.

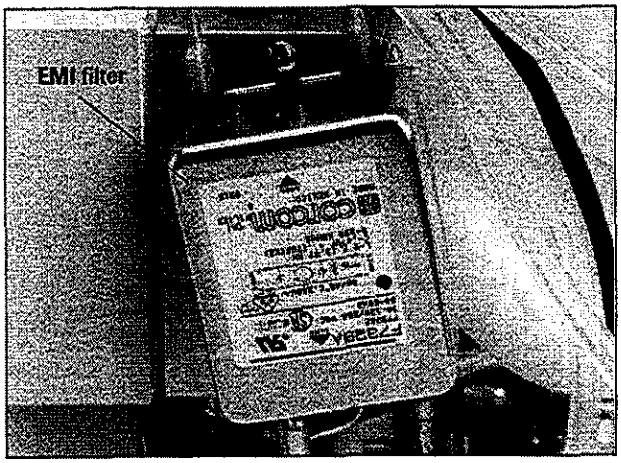

Figure 2-21: EMI Filter

From the EMI filter, power is routed to the power switch and to the power controller PCB. Both "Hot" and "Neutral" AC lines are routed through the power switch. When closed (ON position), AC power is sent to the power supply PCB. The power supply PCB (Figure 2-22) for the *KnightStar 335* is an auto ranging type. Input voltages can be from 100 VAC to 240 VAC, 50 Hz or 60 Hz. Power supply output will remain at +24 VDC producing a maximum of 250 watts throughout the stated input range.

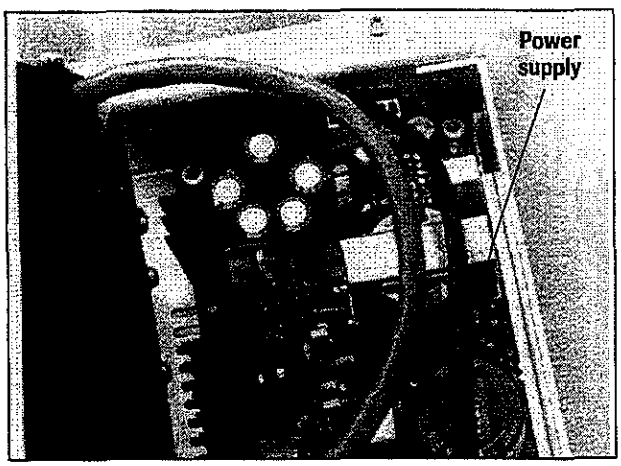

Figure 2-22: Power Supply

The Power Controller PCB (Figure 2-23) receives the +24 VDC output from the power supply. This +24 VDC is used by the voltage regulators to generate +12 VDC, -12 VDC, and +5 VDC. These voltages are used within the *KnightStar 335* to power other electronic circuits and are also routed to the external modules (Control Module Type 1 or infrared module).

Between the power switch and the EMI filter an AC signal is branched off to the power controller PCB. This signal is detected by an AC sense circuit which will illuminate the pilot light, indicating that the unit is plugged into an AC supply whether the unit is "On" or "Off." The AC sense circuit will also charge a back-up power capacitor used to power the audible alarm. If AC power is disconnected with the power switch on, the audible alarm will be powered for at least one minute by the backup power capacitor. Included on the power controller PCB is a circuit which monitors

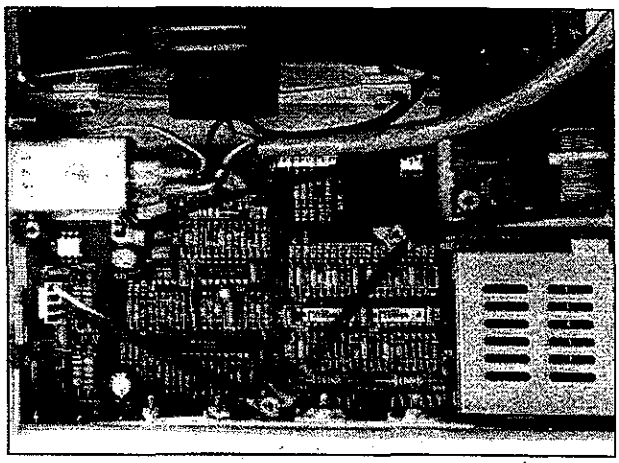

Figure 2-23: Power Controller PCB

the 24 VDC power supply. If the 24 VDC supply falls to an unacceptable level a PFI signal is sent to the microprocessor located on the CPU PCB (Figure 2-24). This signal allows the microprocessor time to shut-down and puts the software into a reset condition.

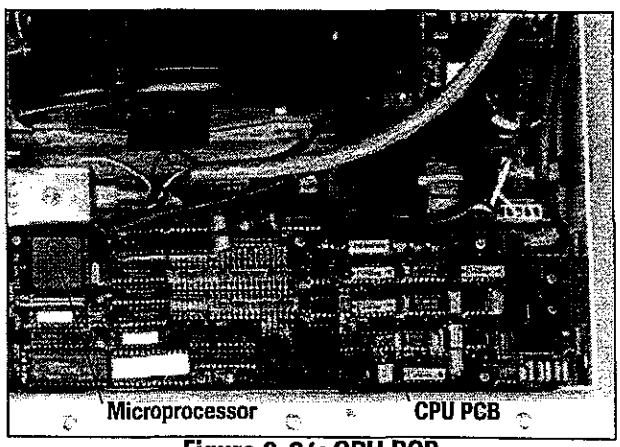

Figure 2-24: CPU PCB

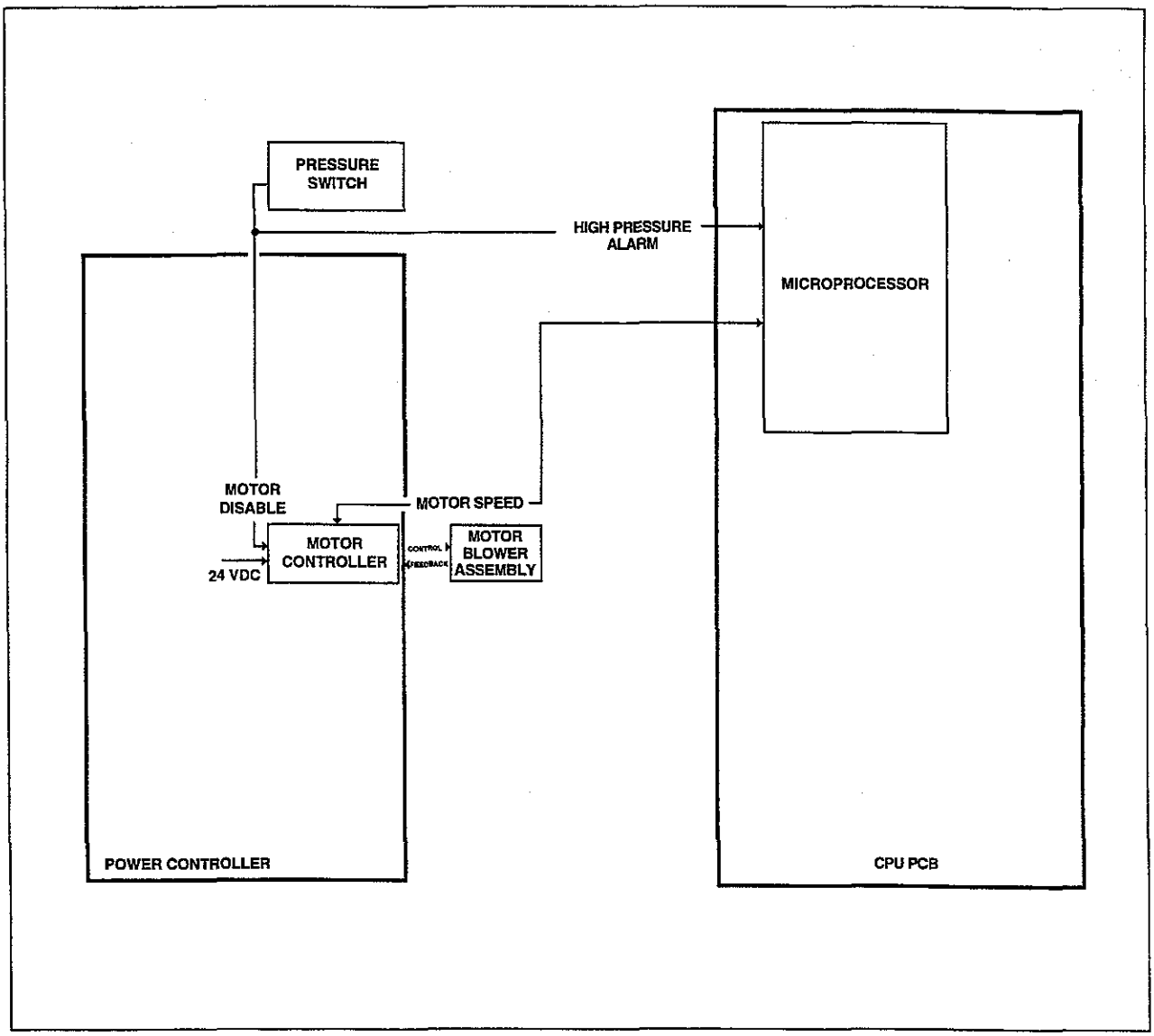

Figure 2-25: Motor Blower Control Circuit

2.4.2 Motor Blower Control Circuit

The microprocessor determines the proper speed for the Motor/Blower Assembly (Figure 2-26) based on the IPAP prescription selected by the operator. During initial-power on testing, the motor/blower assembly is not turned on. After the initial tests are successfully completed, the microprocessor sends a DC signal to the motor controller that translates to a specific motor speed.

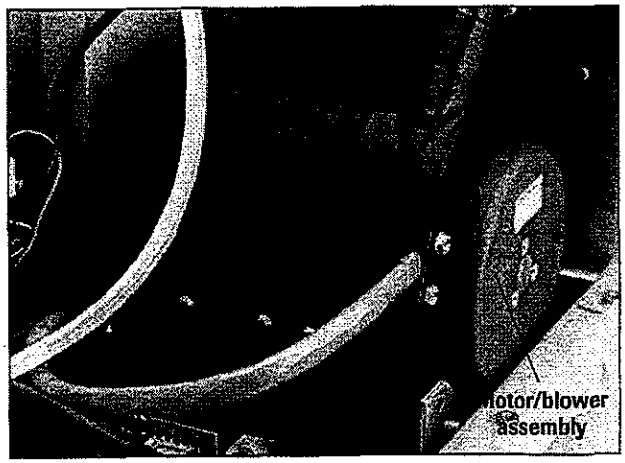

Figure 2-26: Motor/Blower Assembly

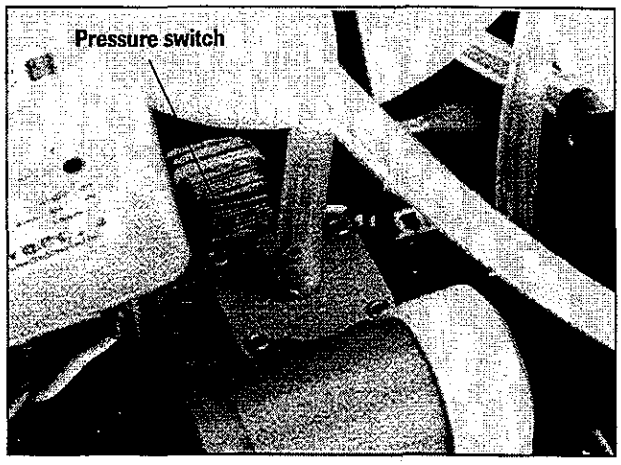

Figure 2-27: Pressure Switch

Motor/blower assembly speed is monitored by the motor controller circuit and compared to the signal sent by the microprocessor. If the actual motor/blower speed does not match the microprocessor's "target" speed, the motor controller adjusts the current of the 24 VDC power being supplied to the motor/blower assembly. The Pressure Switch (Figure 2-27) is monitored by the motor controller and the microprocessor.

If pressure within the *KnightStar 335* exceeds 50 ± 5 cmH_2O, the pressure switch will open. When this occurs, the motor controller circuit shuts the motor/blower assembly down and the microprocessor initiates an audio/visual alarm.

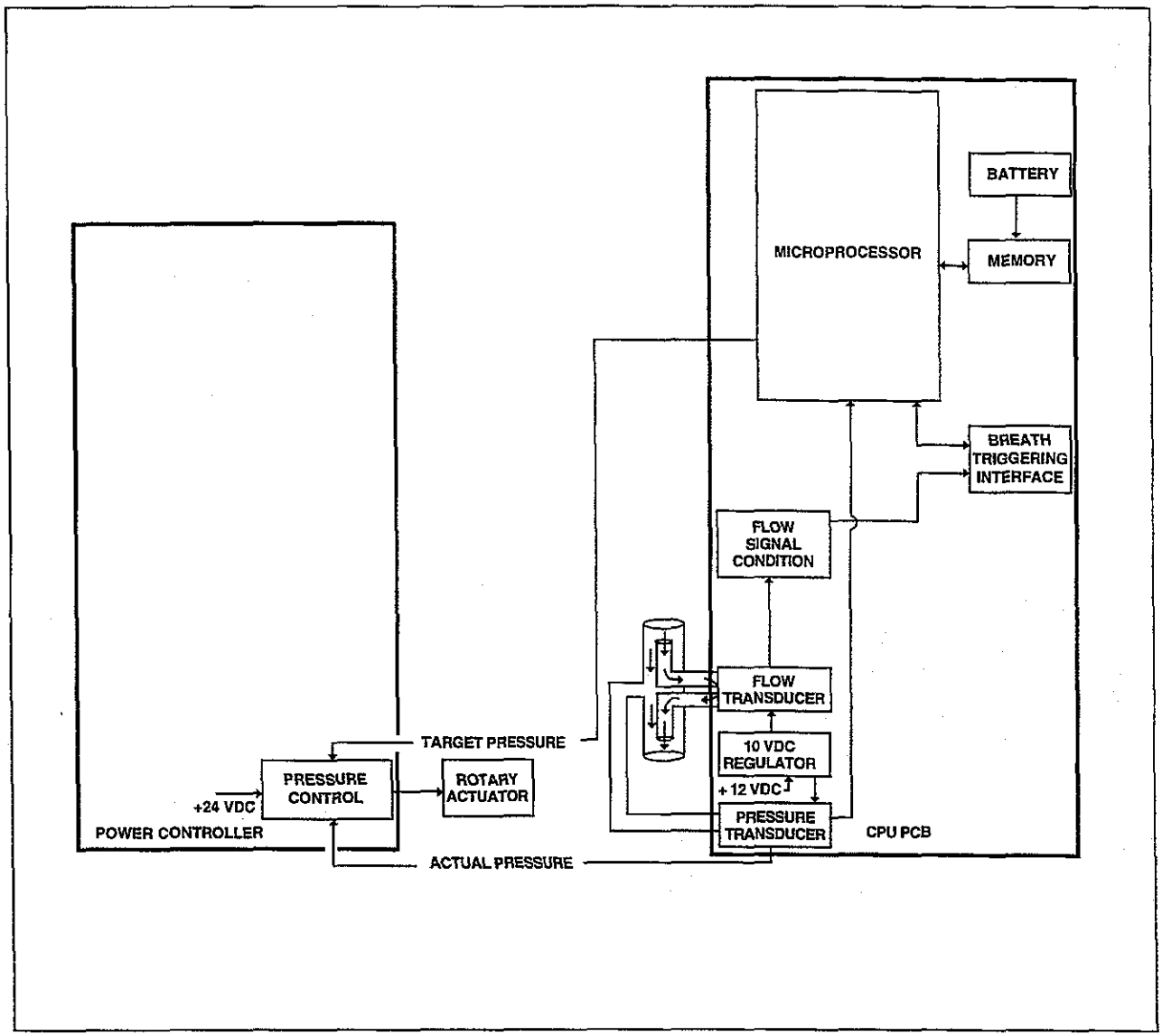

Figure 2-28: Breath and Prescription Control Circuits

2.4.3 Breath and Prescription Control

An 80C196KC microprocessor running at 16 MHz is used as the heart of the CPU PCB. When the unit is first turned on, the microprocessor will perform a series of tests designed to check microprocessor operation. Successful completion of these tests is required before the *KnightStar 335* begins to operate. During the testing, audible and visual indicators are activated to allow the operator to verify proper operation. The cooling fan and the motor/blower assembly do not begin operation until all tests of the microprocessor have been successfully completed. Once the tests have been completed, operation of the *KnightStar 335* is controlled by the microprocessor, based on information from the flow and pressure transducers, memory, and other inputs. Patient pressure is controlled by the rotary Actuator Assembly (Figure 2-29). The pressure control circuit is used to control the rotary actuator assembly. Information gathered by the pressure transducer is sent to the microprocessor and analyzed. The microprocessor sends a signal to the pressure control circuit which is used to determine the position of the rotary actuator assembly. Pressures between +3

cmH_2O and +35 cmH_2O can be maintained by controlling the flow through the supply and dump valves contained in the rotary actuator assembly. (See pneumatics section for details.)

The Flow Transducer (Figure 2-30) is used as an interface between the pneumatic and electronic systems. Flow is diverted to the flow transducer via the pitot tube. An analog signal directly proportional to the flow is generated. Flow values up to 150 lpm can be measured.

Analog flow signals are sent to the breath triggering interface. This information determines the breath phase (inspiratory or expiratory), of the *KnightStar 335*.

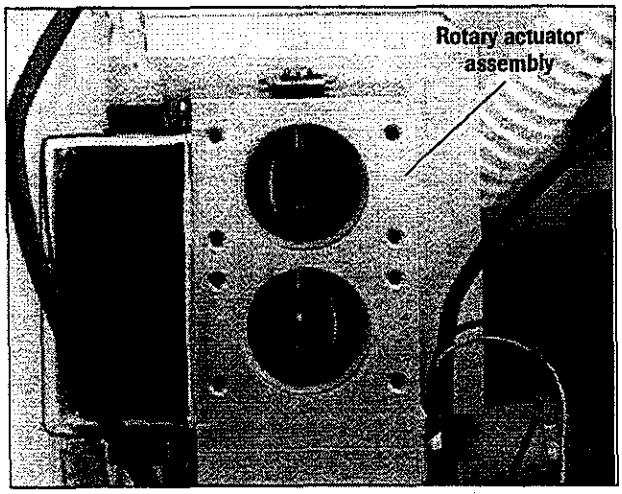

Figure 2-29: Rotary Actuator Assembly

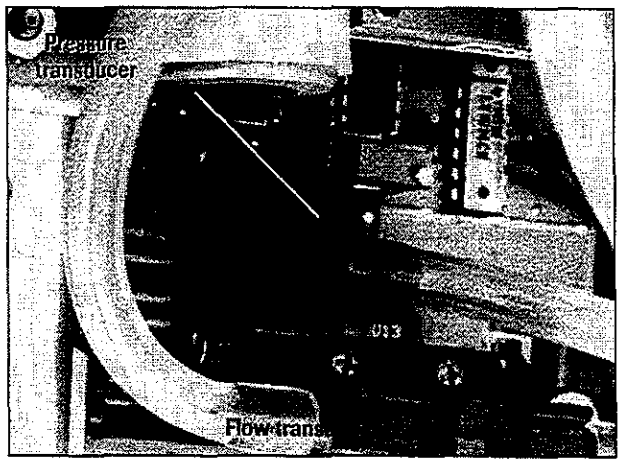

Figure 2-30: Flow and Pressure Transducers

A signal is then sent by the breath triggering interface to the microprocessor which will place the *KnightStar 335* in the correct breath phase. Flow values are used to determine inspiratory and expiratory efforts of the patient. The microprocessor will recognize the patient's efforts as changes in flow, and position the rotary actuator assembly to meet the demands of the patient. Prescription pressures need to be accurately maintained. Pressure to the patient is constantly monitored by the Pressure Transducer (Figure 2-30). The pressure transducer is capable of measuring pressure up to 45 cmH_2O. A feedback loop (described earlier) allows patient pressure to be maintained at the set pressure.

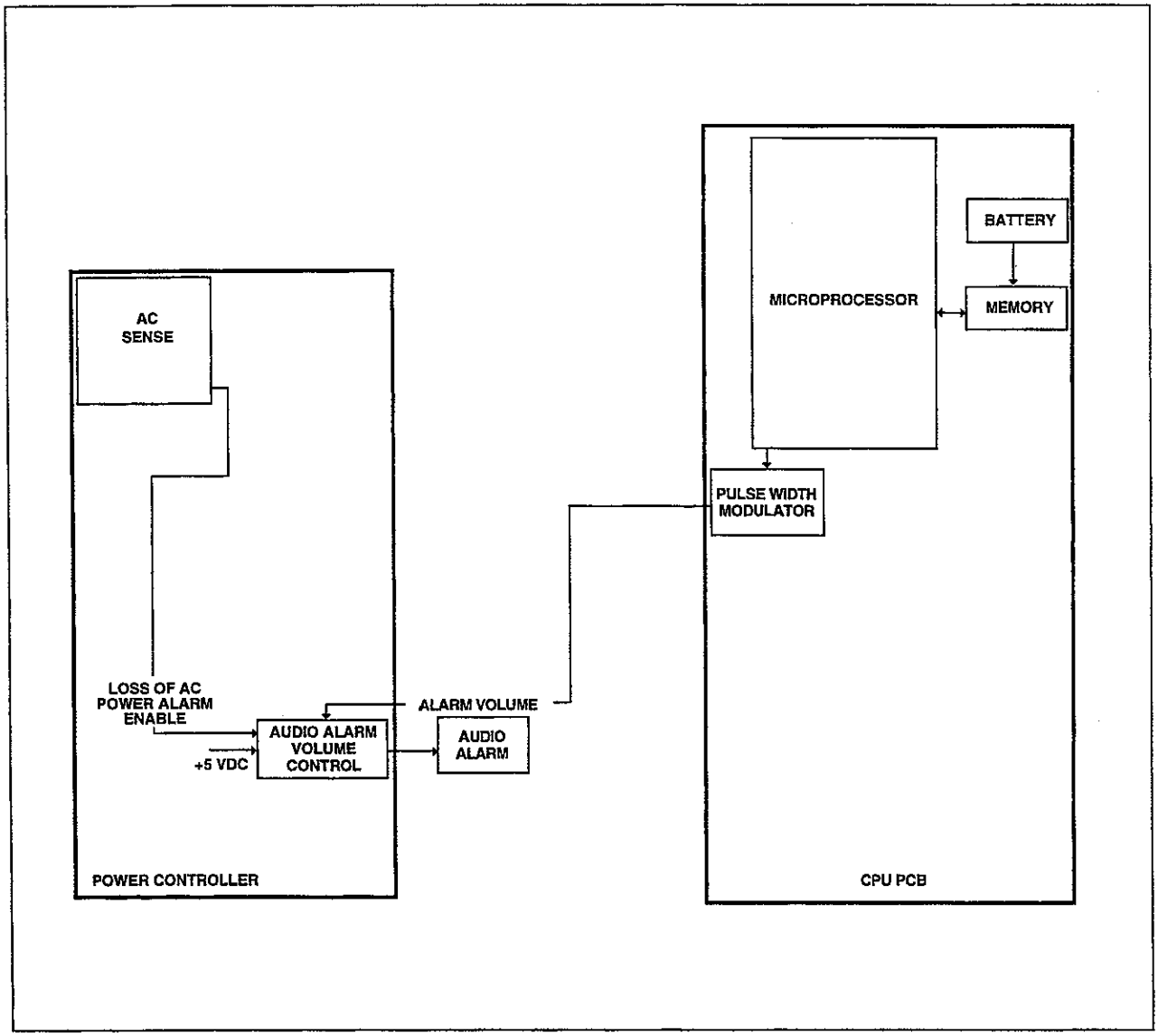

Figure 2-31: Audio Alarm Volume Control Circuit

2.4.4 Audio Alarm Control

Alarm volume is controlled by the microprocessor based on operator selected values. Alarm volume is adjustable from 0.0 to approximately 70 dBA measured at one meter from the back of the unit.

The microprocessor sends a digital signal to the pulse width modulator which creates a pulsating DC signal. The duration of the DC pulse varies with the selected volume. Signals from the pulse width modulator are sent to the audio alarm volume control and are used to produce an audible alarm through the piezo alarm.

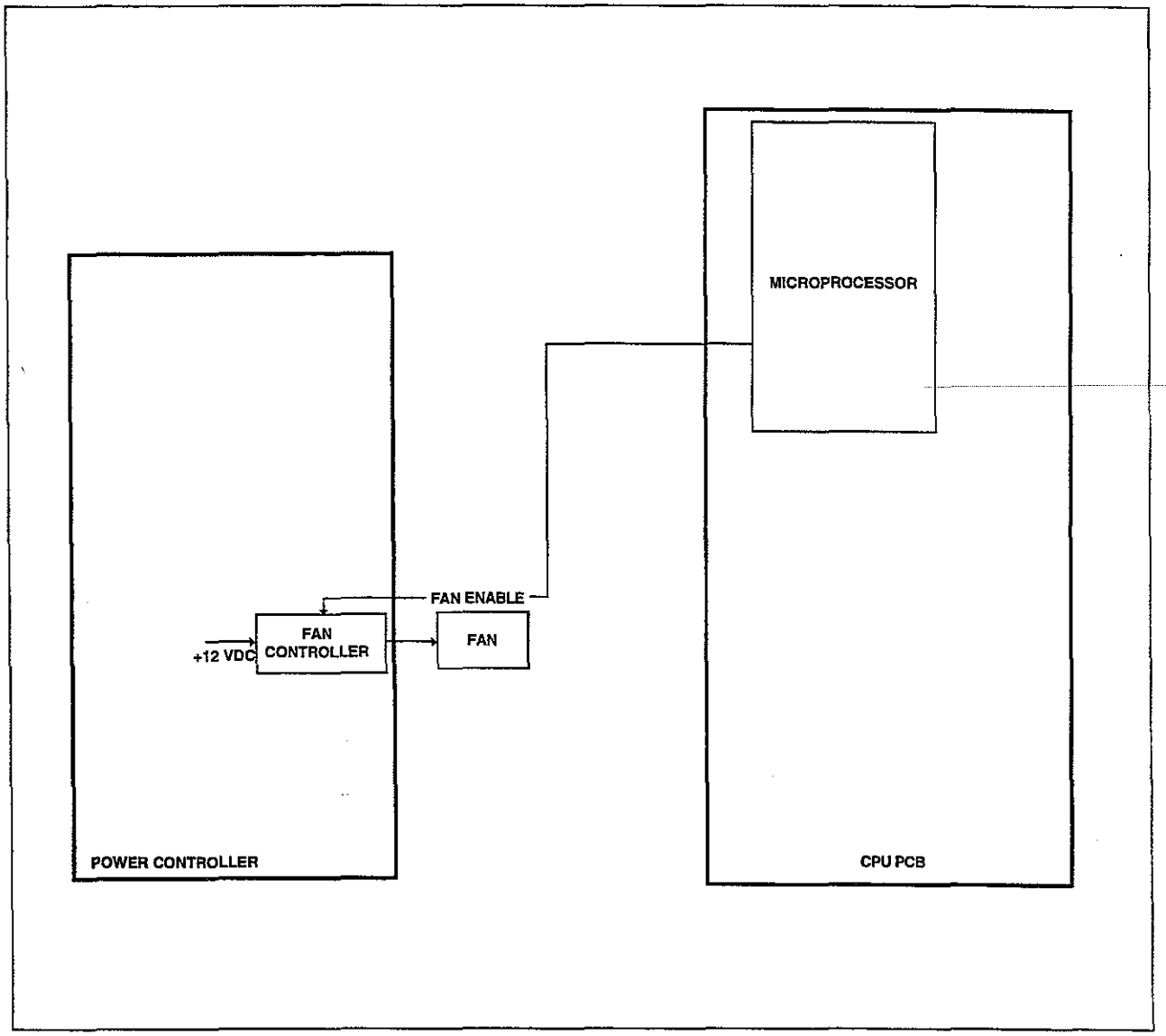

Figure 2-32: Cooling Fan Control Circuit

2.4.5 Cooling Fan Control Circuit

The cooling fan for the *KnightStar 335* is powered by +12 VDC. A fan control circuit is used to apply the voltage to the fan. The fan control circuit is activated by a digital signal from the microprocessor. The microprocessor does not turn the fan on until all system checks have been successfully completed.

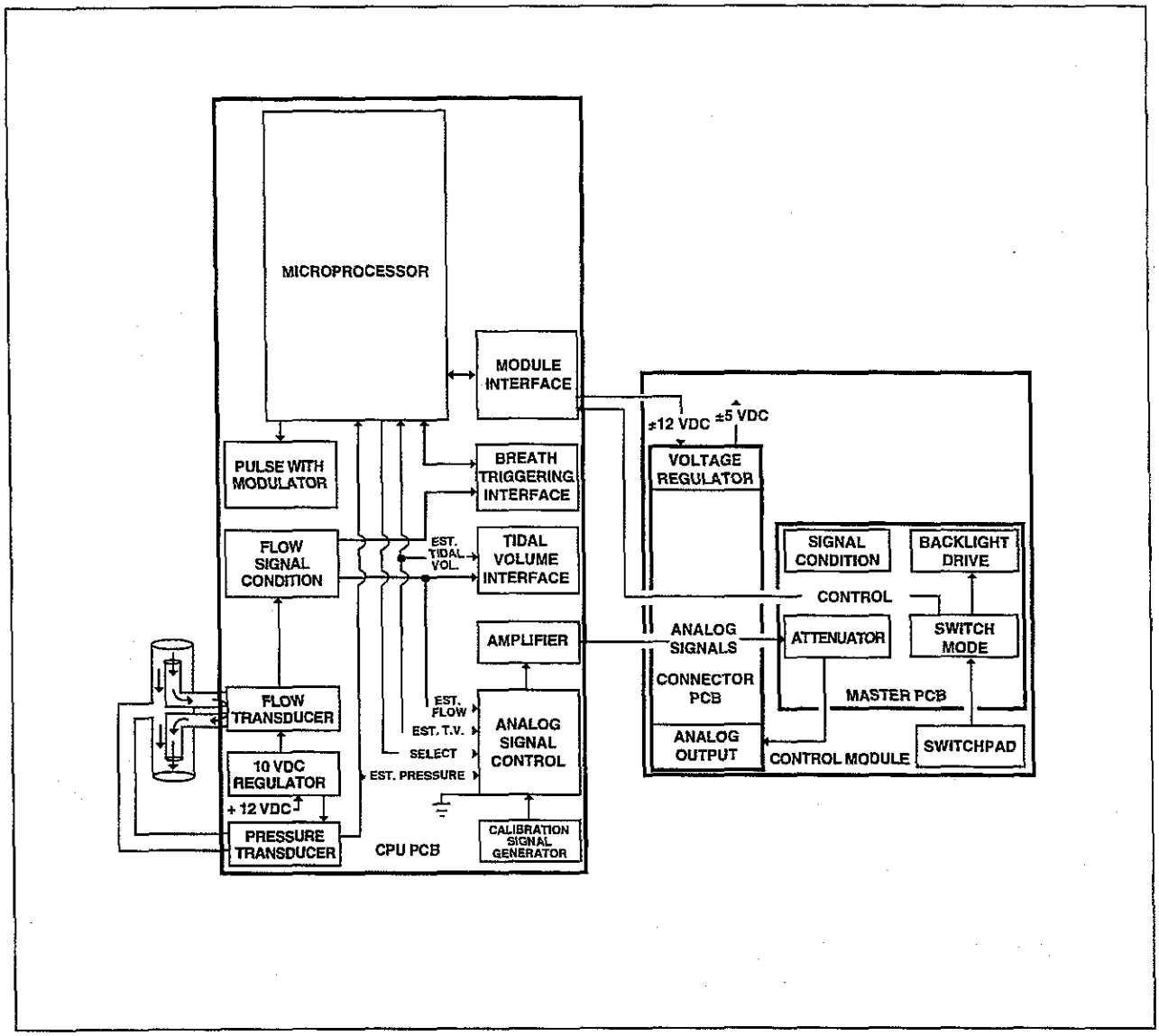

Figure 2-33: Analog Signal and Control Circuits

2.4.6 Analog Signal and Control Circuits

Flow and pressure transducers require a stable DC source. Positive 12 VDC is supplied to a voltage regulator located on the CPU PCB. The regulator has a 10-VDC output which is supplied to the transducers.

An analog output is provided by the transducers. Their output is in direct proportion to the flow or pressure being measured. To remove any DC component from the flow signal, it is passed through the flow signal conditioner circuit. Pressure signals are passed directly to the analog signal control.

Tidal volume is calculated by the tidal volume interface. It receives the flow signal from the flow signal conditioner circuit. An analog signal representing tidal volume is sent to the analog signal control and to the microprocessor. The analog signal control is a multiplexer. A request from the microprocessor will determine which analog signal is passed on to the Control Module Type 1 (Figure 2-34). The analog signal control will send either a calibrate signal or tidal volume, flow.

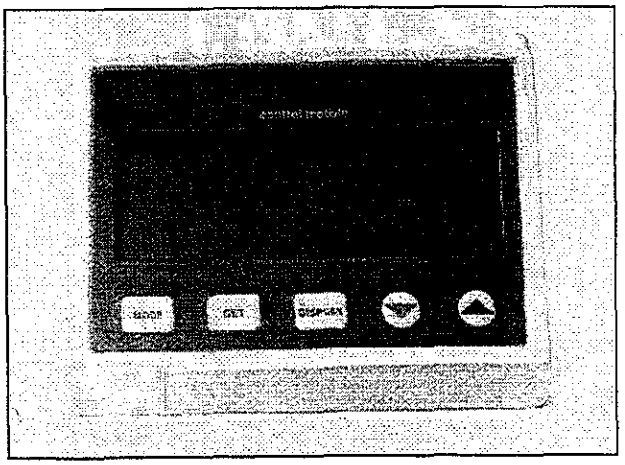

Figure 2-34: Control Module Type I

Control Module Type 1 calibration signals are produced by the calibration signal generator. When requested, a signal of approximately 0.5 Hz is sent, changing from either -0.5 to +0.5 VDC for estimated patient flow and estimated tidal volume, or 0.0 to +0.5 VDC for estimated nasal pressure. These signals are used to calibrate the polysomnograph to the analog outputs of the Control Module Type 1. Analog signals

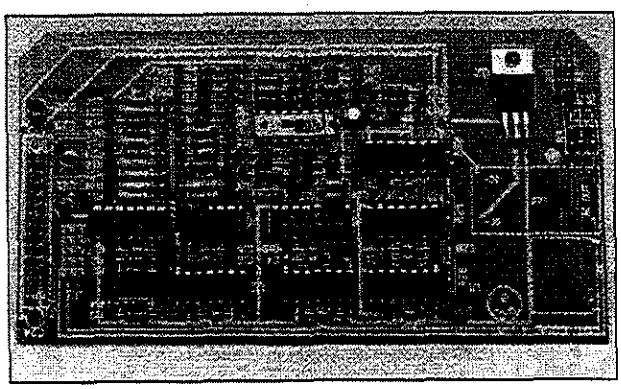

Figure 2-35: Master PCB

passing from the base unit to the Control Module Type 1 may have to travel as much as 100 feet. To account for signal loss an amplifier is used to boost the signals to 5 VDC before leaving the base unit. The Master PCB (Figure 2-35) located in the Control Module Type 1 contains an attenuator which receives the analog signals from the base unit. These signals are reduced by 88% and sent to analog output jacks on the Connector PCB (Figures 2-36 and 2-37) in the Control Module Type 1.

A module interface located on the CPU PCB provides the interface between the CPU PCB and the

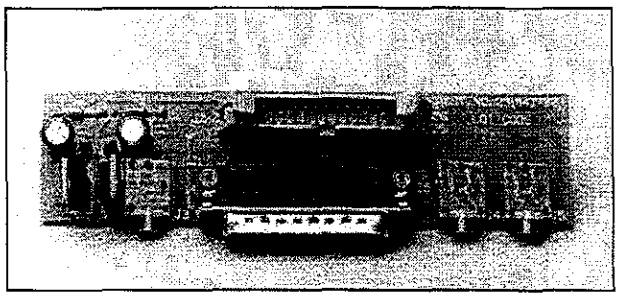

Figure 2-36: Connecter PCB

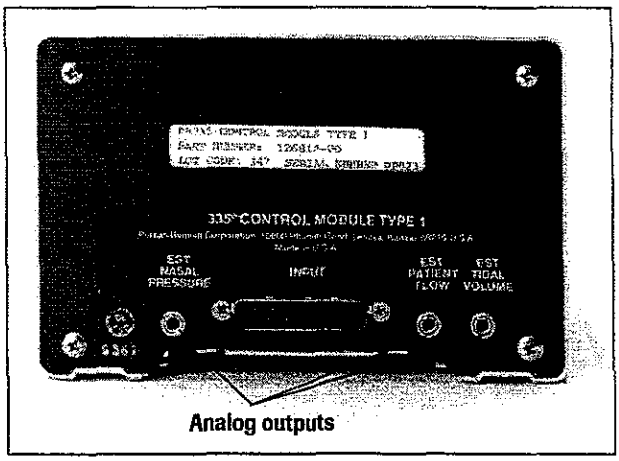

Figure 2-37: Analog Outputs

modules. ESD protection is provided on input and output lines. The interface provides power for accessories attached to the interface connector. Signals that pass through the interface include: input lines for control module keypad switches, output lines for the LCD display, and analog outputs for external instrumentation.

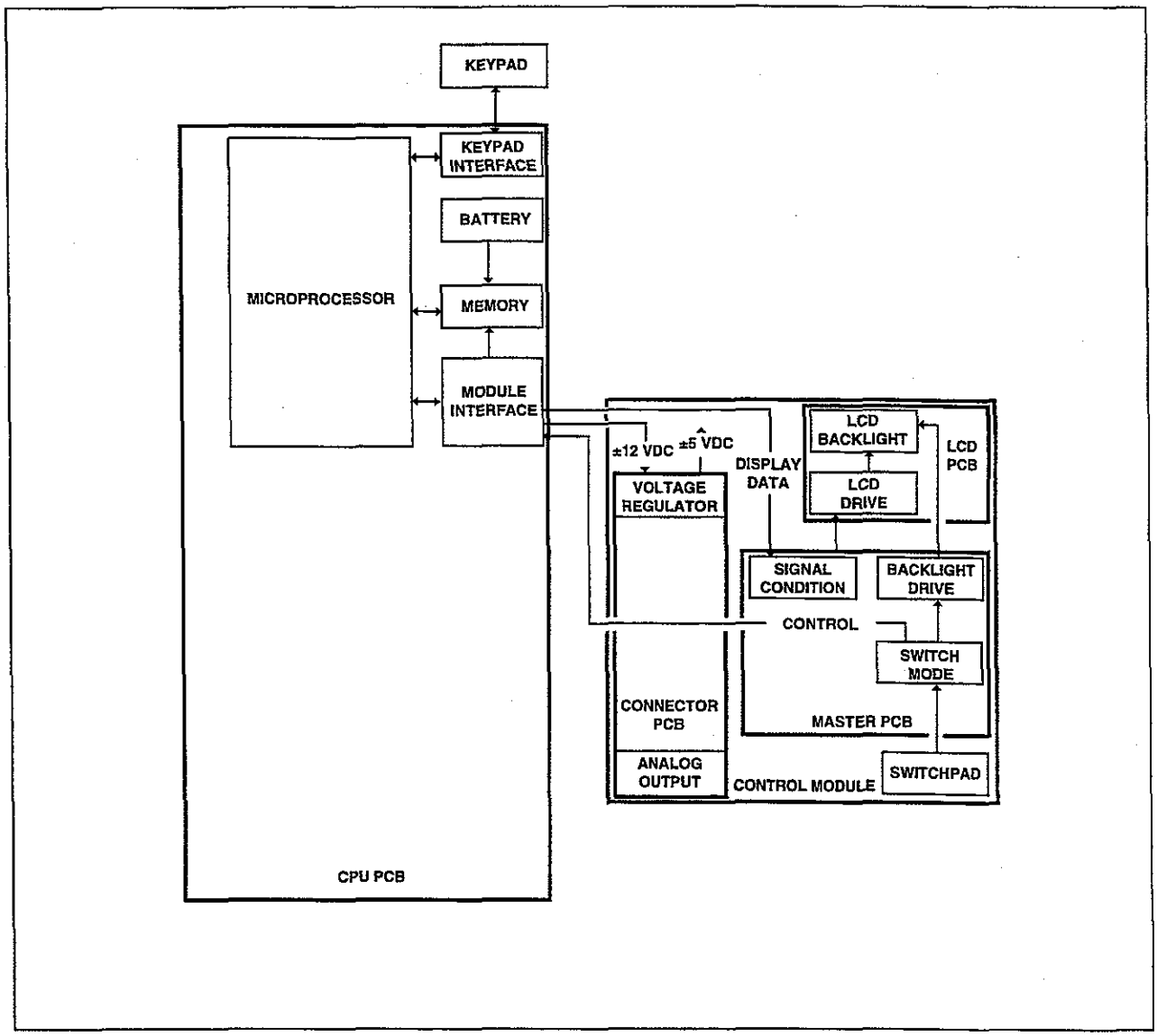

Figure 2-38: User Interface Circuits

2.4.7 User Interface Circuits

Within the Control Module Type 1 is a +5 VDC Voltage Regulator. It receives +12 VDC from the base unit. The output of the regulator is used to power the other circuit boards in the Control Module Type 1.

Operators can make changes to breath parameters and alarm volume, and select between several analog outputs via the Switch Pad of the Control Module Type 1. Five membrane switches are located on the switch pad.

When one of the switches is depressed, a five-volt signal is sent to the Switch Decode circuit on the Master PCB. Here the level of the signal is changed to ±12 VDC and sent to the base unit.

The switch decode circuit also starts a timer in the Backlight Drive circuit. The backlight will remain on for approximately 60 seconds after the last key stroke. Power to the backlight is 115 VAC at 400 Hz.

Keystrokes are sent to the CPU PCB. They pass through the Module Interface to the Microprocessor. The microprocessor will update the base unit to the current selections made by the operator.

Memory is located on the CPU PCB. Program memory and static RAM reside on the CPU PCB. Thirty-two Kbytes are for program memory and thirty-two Kbytes are for static RAM. Static RAM is for general data use and also for the storage of prescription settings. On early units a battery will retain the values when the machine is not being powered by AC. Non-volatile memory is used in current machines. Data stored in memory is used to control the rotary actuator and the audible alarm.

Control Module Type 1 display information is under microprocessor control. The value to be displayed is passed through the module interface where it is converted to ± 10 VDC. The signal condition circuit converts the signal back to 0.0 to 5.0 VDC.

After the signal has been converted it is passed to the LCD Drive. This circuit enables specific segments of the LCD Display (Figure 2-39) to be illuminated and refreshed.

The delay function can be activated by the patient by depressing the delay key on the base unit keypad. The keystroke is decoded by the keypad interface and passed on to the microprocessor to activate the delay. Visual indicators located on the key pad of the *KnightStar 335* are also controlled by this circuit. The microprocessor controls the on/off condition of the lights in response to the operating status of the *KnightStar 335*.

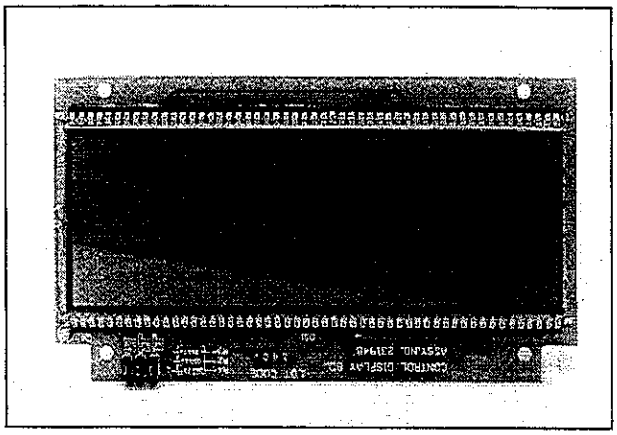

Figure 2-39: LCD Display

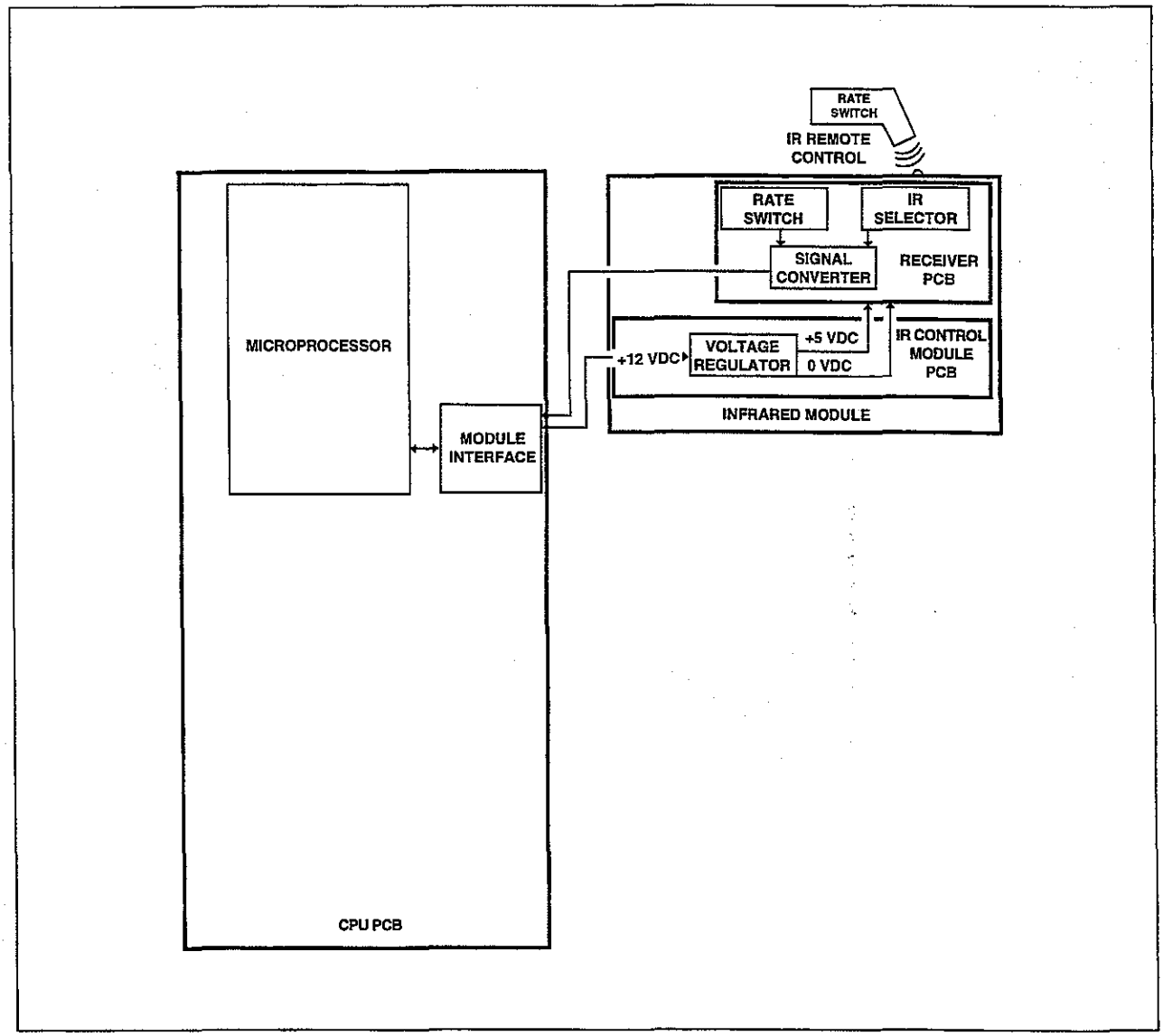

Figure 2-40: Remote Control Circuits

2.4.8 Remote Control Circuits

If the patient chooses, an optional Infrared Module (Figure 2-41) can be used with the *KnightStar 335*. When used with the Infrared Remote Control (Figure 2-42), the patient can turn the unit on and off and activate the delay.

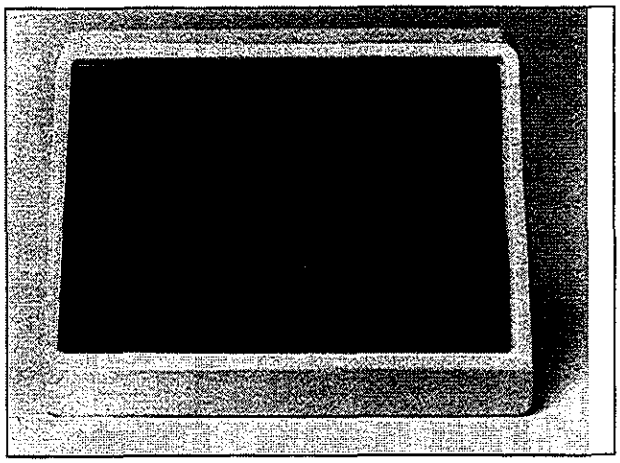

Figure 2-41: Infrared Module

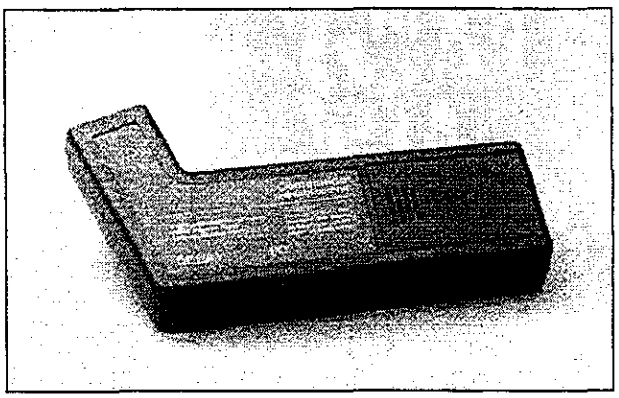

Figure 2-42: Infrared Remote Control

A voltage regulator, located on the IR Control Module PCB (Figure 2-43), is used to produce +5.0 VDC and 0.0 VDC logic voltages for the IR module. This voltage is generated from +12 VDC which is received from the base unit.

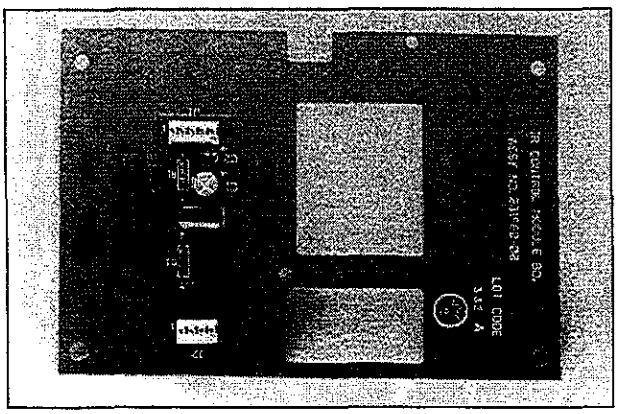

Figure 2-43: IR Control Module PCB

When the patient presses a button on the remote, a data stream in the form of IR light is emitted. The data stream emitted is unique for each button on the remote. IR light is received by the IR detector located on the Receiver PCB (Figure 2-44) and converted to an electrical signal.

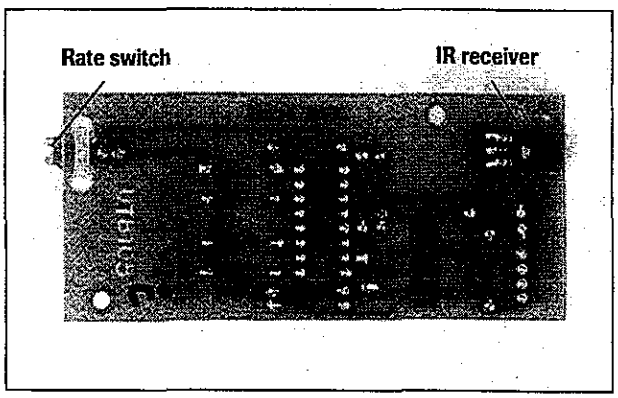

Figure 2-44: Receiver PCB

Electrical signals from the IR detector are received by the signal converter. The signals are amplified to +10 VDC and passed to the module interface in the base unit where they are converted back to 0.0 or +5.0 VDC. Data is then passed on to the microprocessor and analyzed to determine which button was selected by the operator. Communications protocol between the remote control and the IR module can be set to one of two different frequencies. By selecting different frequencies, two units can be independently operated in the same room. The data rate is selected via two rate switches (Figures 2-45 and 2-46), one located on the bottom panel of the IR module and the other inside

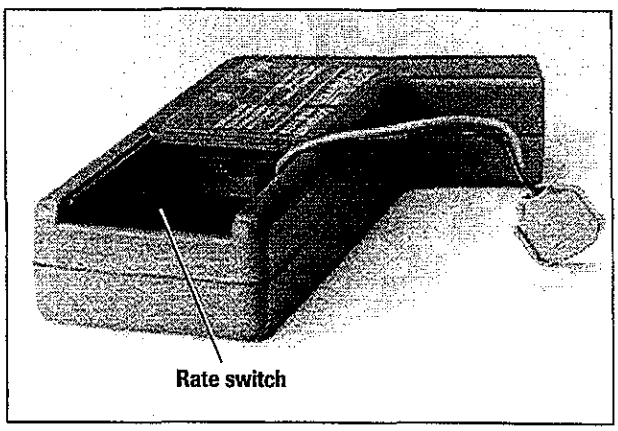

Figure 2-45: IR Remote Control Rate Switch

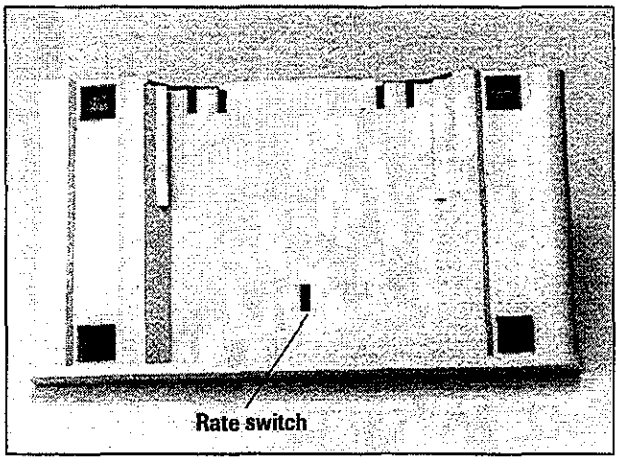

Figure 2-46: IR Module Rate Switch

the battery compartment of the remote control. Both the remote control and the IR module control switches must be set to the same position to allow control of the base unit.

Section 3. Testing and Troubleshooting

This section provides general information for testing and troubleshooting the *KnightStar 335* respiratory support system. Included are electrical and pneumatic testing procedures, where applicable, along with troubleshooting routines of identifying symptom, possible cause and corrective action.

Table 3-1 Acronyms and Abbreviations

AC	Alternating Current
CPU	Central Processing Unit
PCB	Printed Circuit Board

3.1 General Information

The electrical and pneumatic tests should be performed for any one of the following reasons:

1. To determine the cause of operational failure;
2. To check the *KnightStar 335* system's overall operation after repair or replacement of a component;
3. To verify that the *KnightStar 335* system is operating within specification.

3.2 Preparation for Testing

The following tools and test equipment are recommended to test and service the KnightStar 335 system. If equipment other than that specified is used, the substitute must be equal to or better than specified.

Table 3-2 Performance Verification Equipment

Description	Source	Model/Part Number
Electrical Safety Tester	Bio-Tek	Bio-Tek 601 Pro
Calibration Analyzer	Allied Health Care	Timeter RT-200 series
Digital Volt Meter	Fluke Company	87 (true RMS)
Stop Watch	Local Source	N/A
1/2" Gate Valve and Hose Barb Fittings for 3/4" ID Tubing	Local Source	N/A
Syringe, 10cc	Local Source	N/A
Coupling	Nellcor Puritan Bennett	4-003443-00
Tee	Nellcor Puritan Bennett	4-000630-00
Tee	Nellcor Puritan Bennett	4-011521-00
22 mm smooth bore Tube 6'	Nellcor Puritan Bennett	S/133292-00
Small-bore Tube, 6"	Local Source	N/A
Control Module Type 1	Nellcor Puritan Bennett	S-126810-00
Remote Control	Nellcor Puritan Bennett	S-126805-00
Control Module Cable, 6'	Nellcor Puritan Bennett	S-865024-06
Analog Output Cable	Nellcor Puritan Bennett	S-865016-00

3.3 Performance Verification

WARNING:
The *KnightStar 335* is electrically powered. To prevent serious injury or death due to electrical shock, observe standard safety procedures while testing the unit.

WARNING:
If any performance verification can not be obtained, do not return the unit to patient service. Refer to Table 3.3 Troubleshooting.

CAUTION:
Circuit boards contain complementary metal-oxide semiconductor (CMOS) integrated circuits (IC's) which are static sensitive devices. To prevent IC damage, observe standard safety procedures as follows:
- Handle circuit boards by edges only
- Work on grounded conductive mat
- Wear grounded wrist strap
- Store circuit boards in conductive plastic bags

NOTE:
Unless otherwise stated, perform tests from start to finish in sequence.

NOTE:
Tolerances for performance specifications listed in this procedure have been adjusted to compensate for (worst case) test equipment error. The compensations were made by using the manufacturer's specifications for the specific equipment listed in Table 3-2.

Preparation for Testing

1. Remove AC power cord from wall outlet and rear panel of *KnightStar 335*. Remove baffle from air inlet.
2. Remove the fuse drawer and verify fuses with correct ampere rating are installed as indicated on the rear panel of the *KnightStar 335* (Figure 3-1). Reinstall fuse drawer.
3. Remove the housing from the chassis of the *KnightStar 335* by following the instructions in section 4, Table 4-1, procedure 1, steps **a** through **n**.

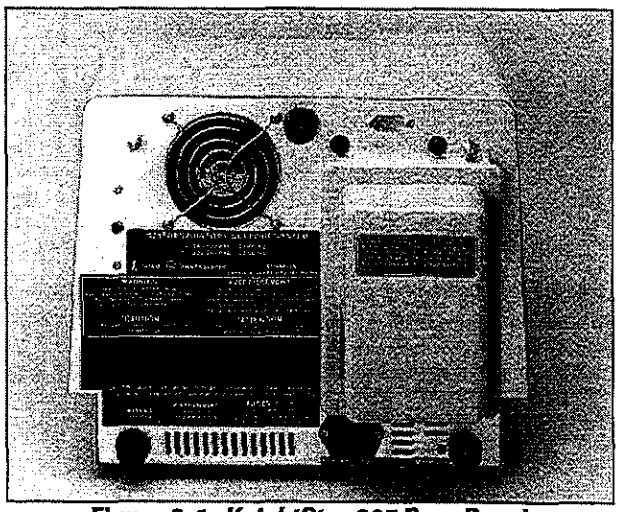

Figure 3-1: *KnightStar 335* Rear Panel

4. Position the housing beside the chassis as shown in Figure 3-2. Reconnect the cable from the CPU, PCB to the housing keypad connector. Reconnect the large-bore air outlet tube to the front panel outlet connector (rotate the elbow on the end of the pitot tube if additional length is required).
5. Connect the Control Module Type 1 to the Top Housing (Figure 3-2).

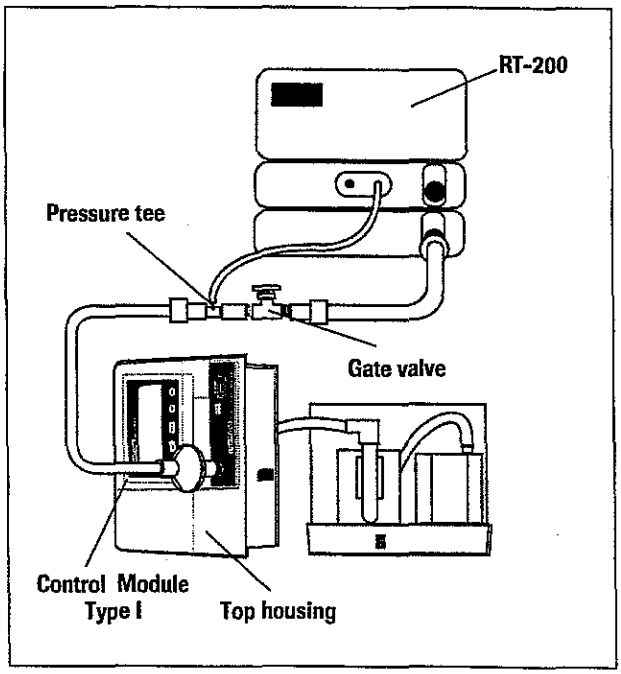

Figure 3-2: *KnightStar 335* Test Position

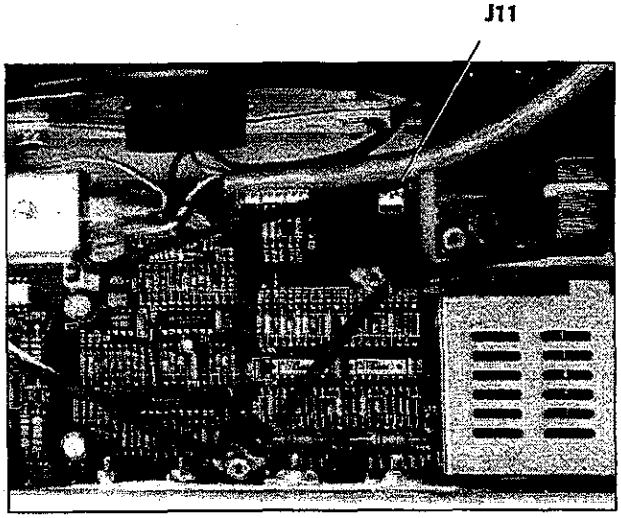

Figure 3-3: Power Controller Board

Maximum Flow Test

6. Connect a bacteria filter, a 6-foot smooth bore tube, pressure tee, gate valve and RT-200 to the outlet of the *KnightStar 335* as shown in Figure 3-2. Set the gate valve to the fully open position.
7. Set the RT-200 to the 250 cmH_2O low pressure range (#12) and zero the display.
8. Set the RT-200 to the 180 lpm air range (#36) and zero the display. Select STP mode and enter the barometric pressure.
9. Turn on the *KnightStar 335* and use the Control Module to select the AC mode with a respiratory rate of 3 and I:E ratio of 1:1 and an alarm volume at zero. Adjust the IPAP prescription pressure to 35 cmH_2O. Adjust the gate valve until the RT-200 reads a flow of 102 lpm or higher. (Use RT-200 range #36.)

NOTE:
Unit will cycle between 35 cmH_2O and EPAP setting.

10. Set the RT-200 to 250 cmH_2O air range (#12) and verify the pressure reading is 35 ± 1.0 cmH_2O.
11. Turn the *KnightStar 335* off and disconnect from the AC power source.

Current Draw Test

12. Connect the *KnightStar 335* to the electrical safety tester (120 VAC) and turn the *KnightStar 335* on.
13. With a flow of greater than 102 lpm (as set by the previous step), verify that the current draw is less than 2.475 amps on the electrical safety tester.
14. Turn the *KnightStar 335* off and disconnect the AC power cord from the electrical safety tester.

Flow Transducer Check

CAUTION:
Use care when removing or reconnecting the flow transducer tubes. Excessive force applied to the transducer may result in damage to the transducer or CPU board.

CAUTION:
Before removing the two tubes from the flow transducer, label each tube so that they can later be re-attached to the appropriate port.

15. Remove the two tubes from the Flow Transducer, Figure 3-4. Using a short piece of small-bore tube, connect the two flow transducer ports together.

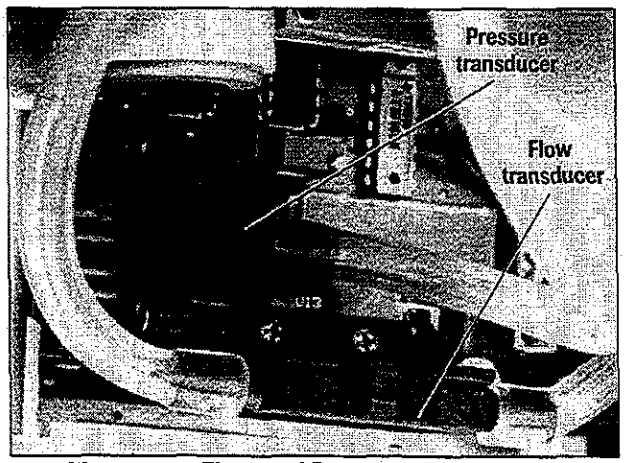

Figure 3-4: Flow and Pressure Transducers

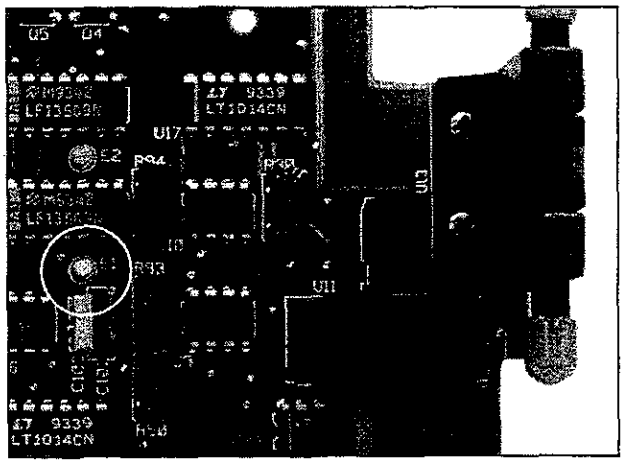

Figure 3-5: CPU PCB Test Point

NOTE:
Easier access to Test Point E1 can be obtained by removing the pressure switch plate.

16. Set the DVM to the DC Volts scale. Connect the positive lead of a DVM to E1 (Figure 3-5). Connect the DVM negative lead to the *KnightStar 335* metal chassis.
17. Turn the *KnightStar 335* on. After 5 minutes verify the DVM reads 0.00 ± 0.049 VDC.

NOTE:
An "Inoperative" alarm may occur during this portion of the test but will not affect the readings taken during step 17.

NOTE:
Adjust R50 on the CPU PC board if necessary.

18. Remove the small piece of tubing between the flow transducer ports and reconnect the original two tubes. Make sure that each of the tubes is connected to the appropriate transducer port.
19. Set the RT-200 to 180 lpm air (#36). Adjust the gate valve until a flow of 150.0 ± 2 lpm is indicated on the RT-200.
20. Verify the DVM reads 5.00 ± 0.2 VDC.
21. Turn the *KnightStar 335* off and disconnect the DVM.

NOTE:
Adust R93 on the CPU PC board is necessary.

Front Panel Indicator Verification

22. Turn the *KnightStar 335* on and use the control module to select the CPAP mode with a prescription pressure of 20 cmH_2O and set the alarm volume to 1. Verify that the front panel POWER ON indicator is illuminated.
23. Adjust the gate valve to produce an RT-200 flow reading greater than 132.6 lpm.
24. Turn the *KnightStar 335* off and wait for the motor to stop turning before proceeding to the next step.
25. Turn the *KnightStar 335* on and start a stopwatch when the motor/blower starts to run. Verify that the front panel LEAK indicator is illuminated and that there is an audible alarm within 60 to 80 seconds. Reset the stopwatch to zero.
26. While starting the stopwatch, disconnect the tubing to the pressure transducer at the manifold (Figure 3-5). Verify the front panel INOPERATIVE indicator illuminates within 15 seconds.
27. Turn the *KnightStar 335* off and reconnect the pressure tube to the pressure transducer.

CAUTION:
Use care when removing or reconnecting the pressure transducer tube. Excessive force applied to the transducer may result in damage to the transducer or CPU board.